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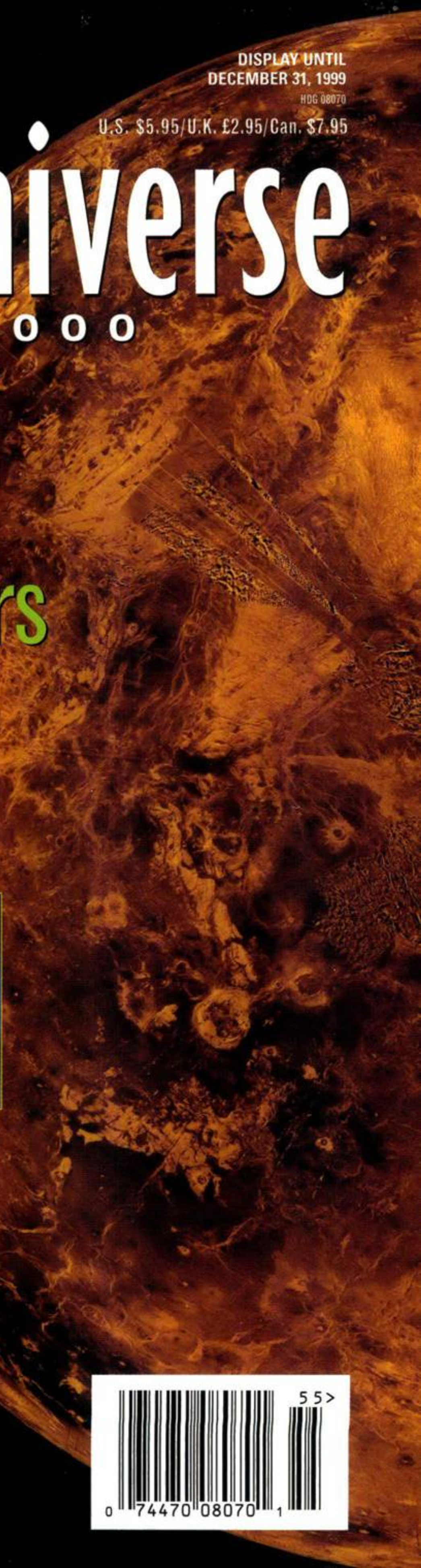

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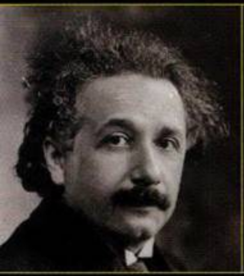

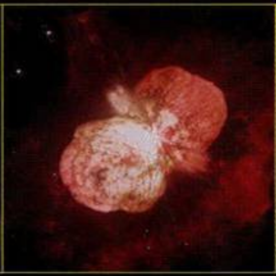

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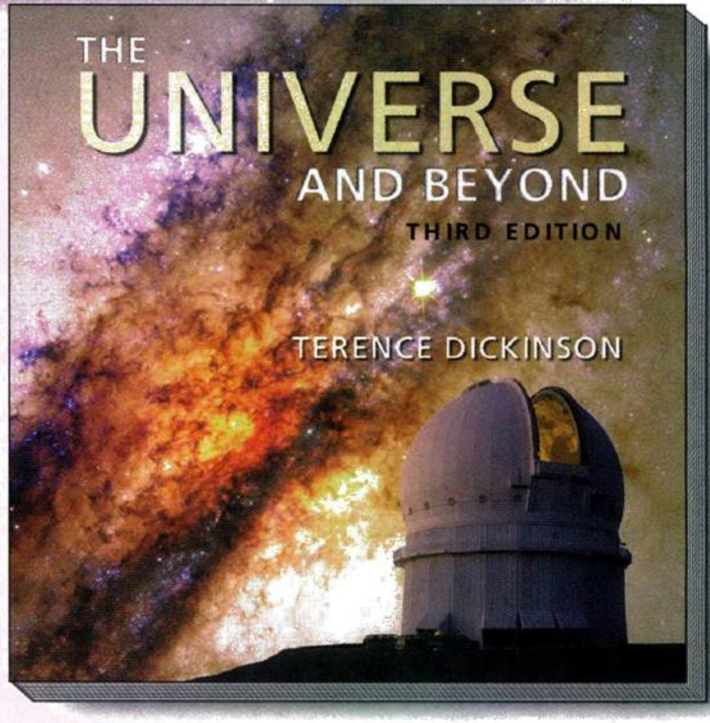
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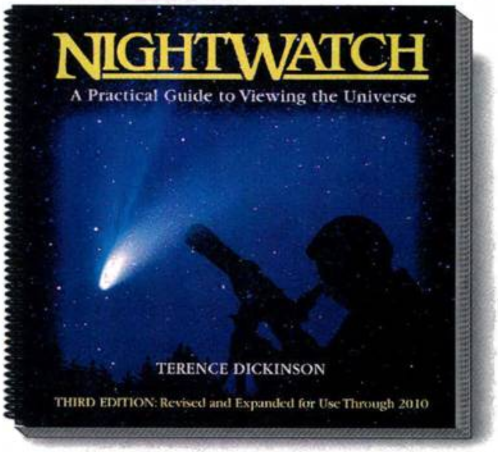
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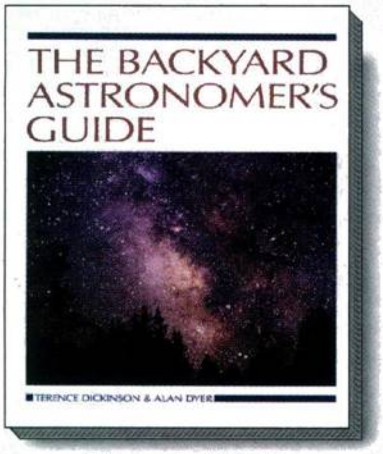
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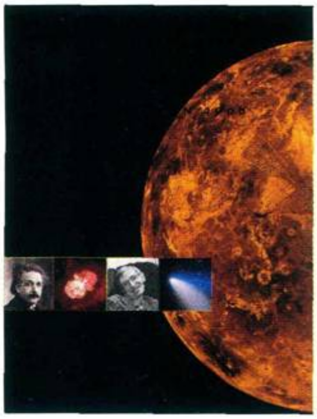

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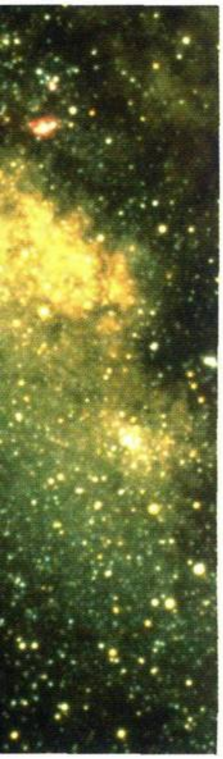

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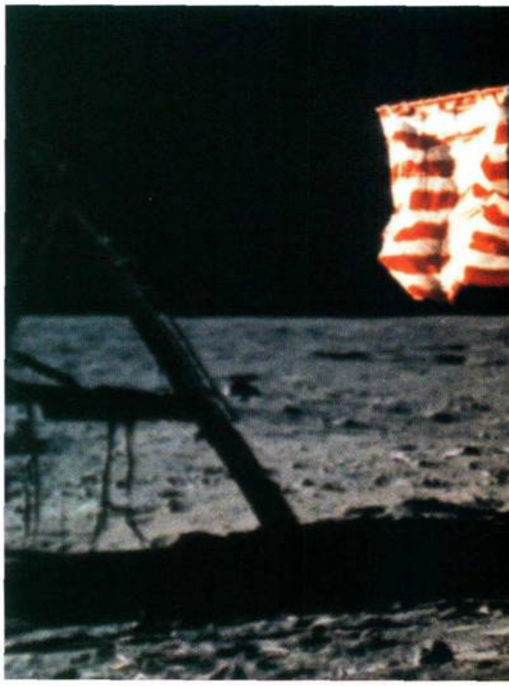

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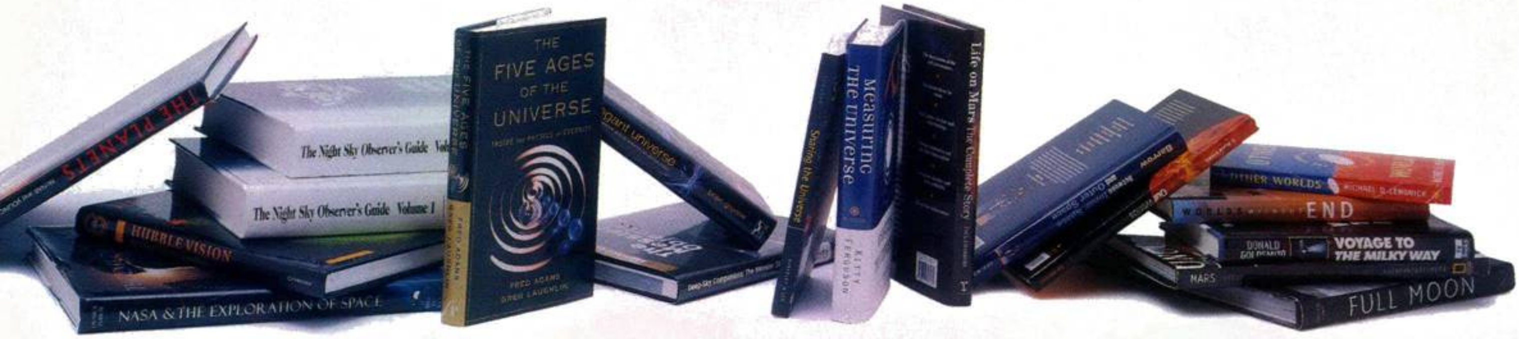
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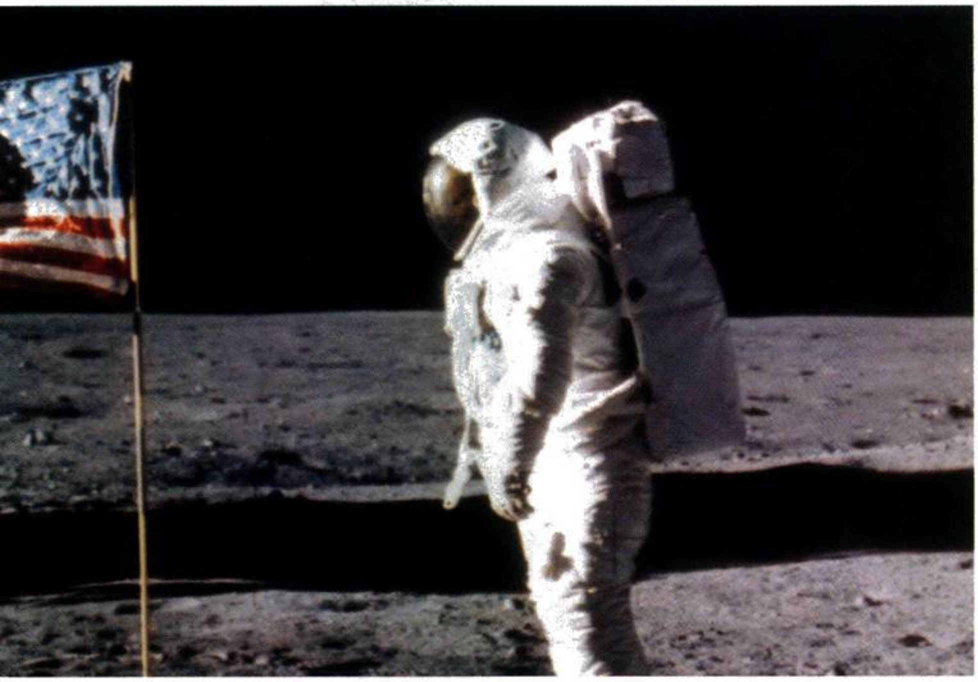

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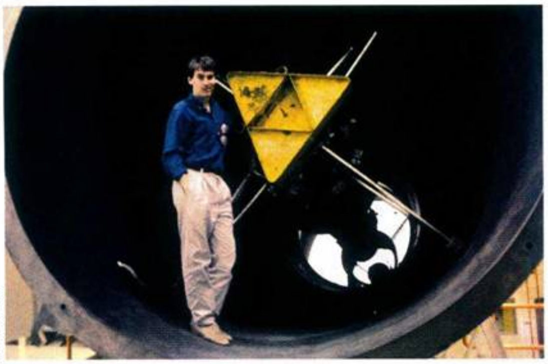
At *the* Eyepiece

Where Have All the Good Times Gone?

One night, walking along the dusty trail to the telescope field at the Texas Star Party, it suddenly hit me like a wave. It was the mid 1980s, and there, spread all around me, were the dim red glowing lights of a new device attached to dozens of sprawling Dobsonian scopes. Some organized technological leap was happening, again (it was something that took place a number of times in the 80s, as the aftermarket explosion of Dob accessories played itself out). The latest device, which absolutely everyone who had a large telescope had to have, was a finderscope called a Telrad. Different from the ordinary high-tech accessory, the Telrad was in fact a low-tech add-on. It was a 1x finder that projected an LED-lighted set of concentric circles onto the sky, allowing you to quickly and accurately point a big scope at some position.


Brian A. Skiff

With the 107-inch at McDonald in the good old days.

Technology had found a niche to help observers gain skill. The Telrad forced observers to learn the sky. They needed to become expert star-hoppers to find objects; to locate the galaxy M101, they would need to start at Mizar and Alcor (the middle star of the Big Dipper's handle) and follow the chain of four stars, 81, 83, 84, and 86 UMa, then move westward from 86 UMa through the middle star of a little line of 7th-magnitude stars, and push their Telrad's bullseye another degree to the west.

I quickly got a Telrad and still use it, and before that point I prided myself on employing only a 6x30 finderscope borrowed from an SCT on my 17.5-inch Dob. Such low-tech finding aids required you to know all those little star patterns that go into finding the Messier and NGC objects. And in learning the sky, you became a more sharply tuned observer of detail in various sky objects by sheer experience.

Now, a dozen years after the mid-80s Dobsonian accessory revolution, another one threatens. This revolution is more typical, promising a microprocessor in every telescope. Even with beginner's models, we're now seeing computers built into scopes, and they offer databases with thousands of deep-sky objects. Now novice astronomers can pride themselves on the old standard of astronomers at professional observatories — of quickly finding dim, distant objects by dialing in some numbers, without having to know the sky. It's a high-tech revolution that suggests observers *not* gain skill. Perhaps that's what technology is for, anyway, to make our lives easier while lessening the work. Perhaps this technology will produce hordes of new observers who never would have gotten into astronomy otherwise. Once they get really good at punching numbers, perhaps these intrepid explorers will want to learn the sky after all, and will use their computer-aided telescopes the old-fashioned way too. Where have all the good times gone? Maybe they're not gone at all, but perhaps we're on the verge of a new blend of techno-stuff and skills that will send observing into an entirely new direction over the coming decades.

Dave Eicher, Editor

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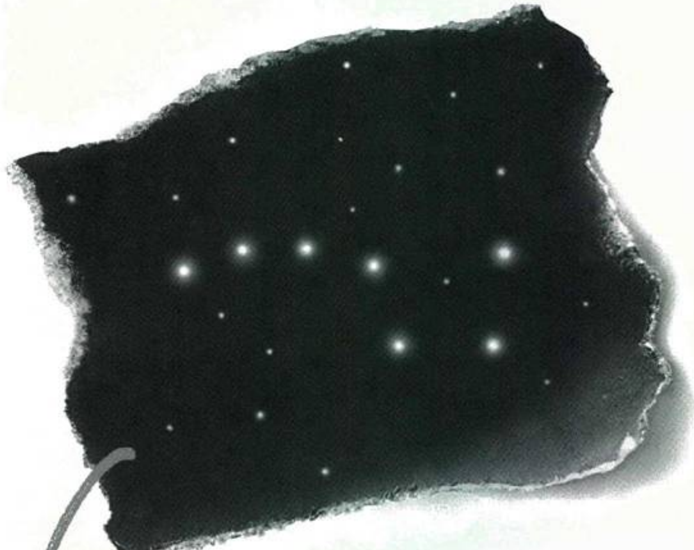

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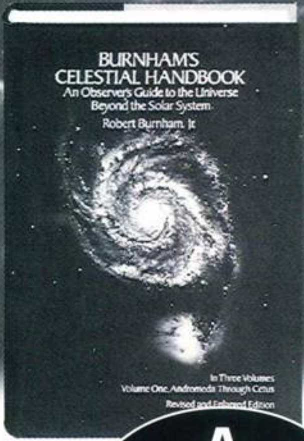
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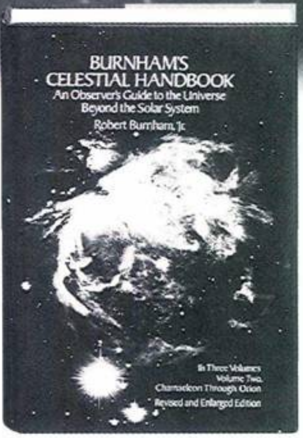
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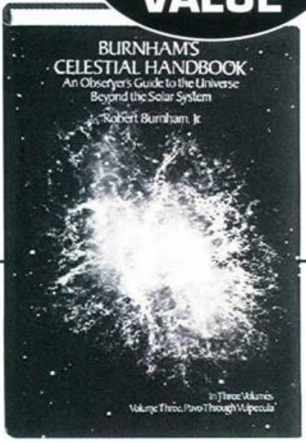
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A Century of Astronomy

by William Sheehan

Apollo 11 on the moon (NASA)

As the 20th century draws to a close, no one would dispute that astronomy has witnessed 100 years of unprecedented progress. Just for a minute, consider the state of the science and what astronomers believed at the end of the 19th century. The features on the moon's surface, which had been scrutinized in great detail by users of small telescopes, were thought to have been fashioned largely by volcanic processes. The planets were still tiny and largely inscrutable disks. (Mars, easily the most studied, seemed to be covered with a network of linear features — the famed canals — which were regarded in some quarters as the work of intelligent beings.) Astronomers were in quest of a planet orbiting closer to the sun than Mercury — and already given a name, Vulcan — because the unquestioned law of universal gravitation developed by Isaac Newton seemed to require its existence. And speaking of the sun, no one knew what made it or any of the other stars in the sky shine.

Outside our solar system, a new star had recently appeared in the Andromeda "Nebula," and its apparent brilliance seemed to prove that the nebula could not lie outside the confines of our own Milky Way. Astronomers widely debated the nature of the so-called white nebulae (including the spirals), but on balance the evidence seemed to suggest to many that they were solar systems in formation rather than island universes. Astrophysics was just in its infancy, and optical astronomy was the only game in town — radio, x-ray, and infrared astronomy had not yet begun.

The 19th century had certainly seen remarkable breakthroughs of its own: the first accurate measures of the distances to stars, the introduction of spectroscopy and photography, and the advent of astrophysics. When future historians consider the legacy of the 20th century, what will they see as the major developments? What follows are a few educated guesses, arranged decade by decade.

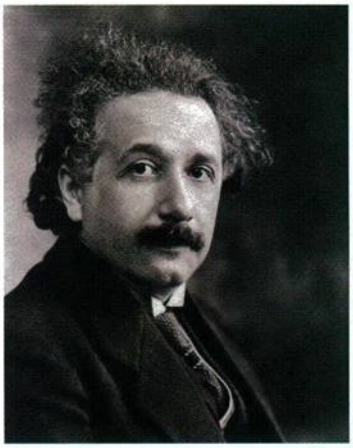
1900s

1900
Max Planck discovers that energy comes in discrete packets he calls "quanta"

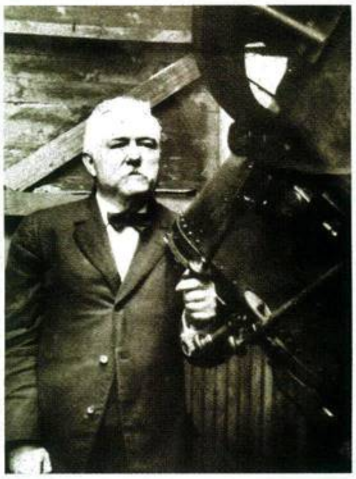
1901
Annie Jump Cannon publishes her first catalog of stellar spectra

1905
Albert Einstein publishes his theory of special relativity

1908
A comet explodes over the Siberian region known as Tunguska


Albert Einstein (Yerkes Observatory)

The First Dark Matter


Edward Emerson Barnard (Yerkes Observatory)

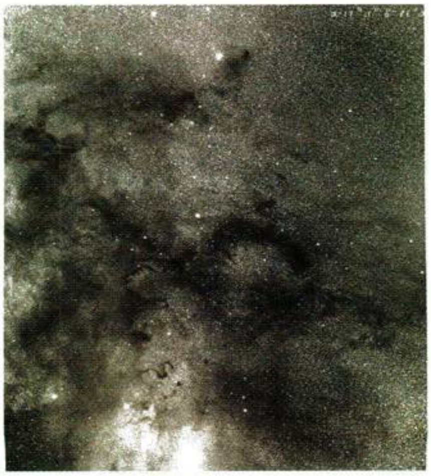
In some ways, the 20th century could be described accurately as the century of invisible astronomy. Previous astronomers had concerned themselves with the luminous objects in the heavens, such as stars and bright nebulae. But such objects represent only a small fraction of all the matter in the universe. It's ironic that the exploration of the universe's dark matter commenced with the work of an astronomer who was widely regarded as having the keenest vision of any then alive, Edward Emerson Barnard.

Barnard grew up in poverty in Nashville, Tennessee, just after the Civil War, but at the age of nine he was apprenticed at a photographic gallery. Soon afterward he became interested in astronomy, later making a name for himself as a successful discoverer of comets. He went on to a career as a professional astronomer at Lick and Yerkes observatories. Above all, he was able to apply the skills he had acquired in his many years at the photographic gallery to his passionate pursuit of astronomy.

Photography proved one of the most important legacies of the old century for the new. Indeed, the great researches of modern astronomy would have been impossible without it. In the early days of wet-process plates, astronomical photography had been useless, but by the 1880s dry plates were coming into general use. In 1882, both the transit of Venus and a spectacular sun-grazing comet were recorded for all time on photographic plates.

At Lick Observatory in the 1890s, Barnard used an antique portrait lens to pioneer wide-angle photography of the Milky Way and comets. He puzzled over the dark markings in the Milky Way that appeared on his plates. Were they actual holes in the heavens, as William and John Herschel had believed, or clouds of dark matter obscuring the distant stars? Haunted by the question, in January 1905 he took a specially designed photographic telescope to California's Mount Wilson and spent seven months feverishly photographing the Milky Way. Barnard's hours of work would have horrified any medical man. One of his colleagues later recalled that Barnard considered sleep a sheer waste of time, and for long intervals he would forget it altogether.

Barnard was the Ansel Adams of the Milky Way; in some ways, his photographic plates have never been surpassed. They splendidly reveal the large dark regions in Ophiuchus and Scorpius that appear almost entirely free of stars. After a long struggle with himself, he concluded that these were indeed places where the light of the distant stars was being absorbed by obscuring clouds of dark matter.


The Snake Nebula (*Atlas of Selected Regions of the Milky Way*)

Robert J. Trumpler of the Lick Observatory proved decisively in 1930 that these were, in fact, dust clouds along the plane of the Milky Way. Barnard, however, will always be remembered as the dark matter pioneer. Even today, a great deal of dark matter remains to be accounted for. Not all of it is the obscuring dust that Barnard discovered, and it seems increasingly likely that much of it will prove to be exotic matter different from the kind that forms the stars, Earth, and even ourselves. In the entire universe, probably less than 10 percent of the matter consists of that which we can actually see.

The Search *for* More Light

George Ellery Hale (Carnegie Observatories)

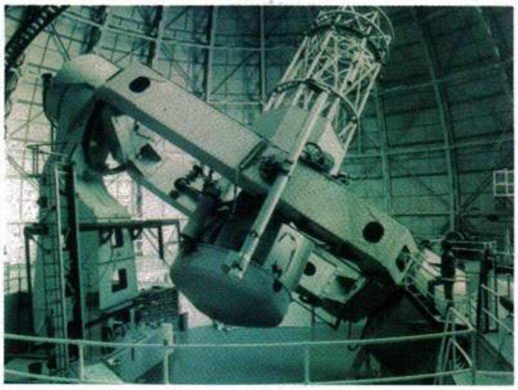
While Barnard was trying to determine the nature of the Milky Way's dark matter, a colleague of his, George Ellery Hale, pursued an equally passionate quest. Hale's constant wish was for more light. At the end of the 19th century, the world's most powerful telescope was the 40-inch refractor at Yerkes Observatory in southern Wisconsin. Although funded by Chicago elevated-train magnate Charles T. Yerkes, it was Hale's dream-child. Yet even the Yerkes telescope failed to satisfy Hale. A product of Chicago industrial expansionism, where one of the architects had once said, "Make no little dreams; they have no power to stir men's blood," Hale set out on a lifelong quest to build ever larger and more powerful telescopes with which to collect light from the far reaches of space.

Hale was the son of a millionaire who had acquired his fortune by designing elevators for the skyscrapers that helped shape the Chicago skyline in the years after the Great Fire. He became acquainted with Chicago's well-known double-star observer, Sherburne W. Burnham, but had little interest in the classical positional astronomy practiced by most 19th-century astronomers. Instead, he later recalled, "I was a born experimentalist. I was bound to find the way of combining physics and chemistry with astronomy."

For a long time, learning the chemical makeup of stars had seemed hopelessly beyond reach — indeed, the French philosopher August Comte said in the middle of the 19th century that the chemical composition of stars was one thing we would never be able to learn. The spectroscope changed all that. When the light from chemicals heated in a laboratory is spread into a spectrum by a prism or diffraction grating, it shows characteristic sequences of lines that allow the chemicals to be identified in much the same way as a fingerprint allows identification of a person. These lines can also be seen in the spectrum of the sun or a star. When disentangled, the lines furnish clues to the object's makeup.

Hale was a remarkably intelligent, energetic, and restless individual. He probably had what would be described today as manic-depressive illness; he certainly was subject to extreme mood swings. As a young man, his mood was elevated most of the time, and he had what could be considered delusions of grandeur — but somehow Hale was usually able to make his dreams a reality. He founded Yerkes Observatory while still in his twenties, then moved west to California and founded the Mount Wilson Observatory in 1903.

He realized that the future lay not with refractors such as the 40 inch at Yerkes but with large reflectors — and was the driving force behind the Mount Wilson 60 inch, which saw first light in 1908, and the 100 inch, which went into operation in 1919. In photographs taken with the 60 inch at the beginning of World War I, his colleague George Willis Ritchey began identifying erupting stars known as novae in spiral nebulae similar to those commonly observed in our own Milky Way. Their apparent faintness suggested strongly that the objects in which they were located must lie at stupefyingly vast distances. It was Hale's large telescopes that would soon point the way to the galaxies and the expansion of the universe. It's hard to imagine where we would be today if not for the driving force of Hale.


The 100-inch Hooker Telescope (Carnegie Observatories)

1910s

1910

Hertzsprung-Russell diagram published for first time

Great January Comet, visible in daylight, becomes brightest of century

1911

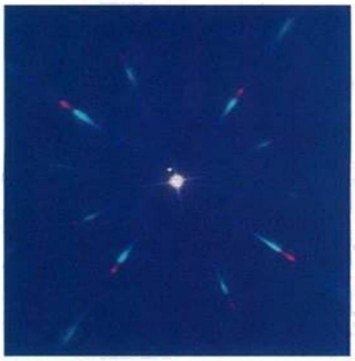
Ernest Rutherford announces the nuclear structure of atoms

1912

Henrietta Leavitt deduces period-luminosity relation of Cepheid variables

1913

Niels Bohr develops theory of atomic structure


Sirius A and B (McDonald Observatory)

1915

Albert Einstein publishes his theory of general relativity

Walter Adams identifies first white dwarf (Sirius B)

1917

100-inch Hooker Telescope on Mount Wilson completed

1916

Karl Schwarzschild determines size of black holes

1918

Harlow Shapley determines the size of Milky Way Galaxy and the sun's location in it

1919

Arthur Eddington provides support for general relativity with photographs of total solar eclipse

1920s

1920
Frances Pease and John Anderson measure diameter of first star (Betelgeuse) beyond the sun

1923
Edwin Hubble identifies Cepheids in M31

1925
Cecilia Payne-Gaposchkin establishes temperature scale for stellar atmospheres

1926
Robert Goddard launches first liquid-fueled rocket

1927
Abbé Georges Lemaître proposes Big Bang origin of universe

Werner Heisenberg discovers the uncertainty principle

Edwin Hubble (Carnegie Observatories)

1928
Paul Dirac theorizes the existence of antimatter

1929
Edwin Hubble deduces that the universe is expanding

Cecilia Payne-Gaposchkin (Katherine Haramundanis)

Hubble's *Enduring* Legacy

Andromeda Galaxy (Bill and Sally Fletcher)

The early years of the 20th century were dominated by a few great astronomers, among them W. W. Campbell of Lick Observatory, E. C. Pickering of Harvard, and, of course, Hale. None, however, would loom larger than Edwin P. Hubble. Hubble attended high school in Chicago and law school at the University of Chicago, although he never practiced law.

His impressive stature (over six feet) and powerful physique made him a natural athlete, and he once declined, wisely, an invitation to box the then world heavyweight champion, Jack Johnson. His all-around talents helped him win a Rhodes scholarship at Oxford University in England. He enjoyed being an Oxford swell and acquired a plummy English accent and a penchant for tweeds that he never lost, even after returning to the States. His personal manner was always rather stiff and standoffish, and in his later years he much preferred the companionship of Southern California's celebrities and movie stars to that of fellow astronomers.

After Oxford, Hubble returned to the University of Chicago's Yerkes Observatory as a research assistant. He wrote his Ph.D. thesis on nebulae — one of the hitherto great, unrecognized growth areas of modern astronomical research. Many nebulae had been recognized as faint fuzzy patches by Charles Messier and William Herschel at the end of the 18th century, but their nature had long been debated. Only a few years earlier, for instance, the great Andromeda Nebula was referred to as "a mystery in all probability never to be penetrated by man." Was it a relatively nearby cloud of gas and dust swirling around its already condensed center — a prototype of the cloud from which the solar system was thought to have been spawned according to the theories of Laplace and Kant? Or was it an island universe, a vast system of stars like the Milky Way so magnificently revealed in Barnard's wide-angle photographs?

In 1919, just as the 100-inch telescope was going into operation, Hubble was hired as an astronomer at Mount Wilson. He was the right man in the right place at the right time. He was able to draw on recent work by Henrietta Leavitt of Harvard College Observatory, who from studies of the Small Magellanic Cloud had discovered that the periods of certain variable stars, known as Cepheids, vary with their intrinsic brightness. This provided a powerful measuring stick across interstellar space.

At the time, the 100-inch telescope on Mount Wilson was the only one in the world capable of detecting Cepheid variables in the Andromeda Nebula. In early 1924, Hubble used it to identify one Cepheid and proved that it lay more than 1,000,000 light-years from Earth. There could no longer be any doubt that Andromeda and similar spirals were vast star systems far beyond the confines of the Milky Way.

Yet Hubble was not finished. In 1929 he made an even more important discovery — indeed the most important astronomical discovery of the century. He plotted the distances of galaxies against the shifts to longer wavelengths in their spectral lines, measured by V. M. Slipher of Lowell Observatory and Hubble's own colleague, a former mule-driver named Milton Humason, and discovered the expansion of the universe. If the galaxies are currently hurtling apart from one another, it follows that in the past, all the matter of the universe was scrunched together into a very small space. The universe thus began at a definite point in time between 10 and 15 billion years ago, in a hot, superdense cauldron of energy, and has been expanding ever since — the gist of the big bang model.

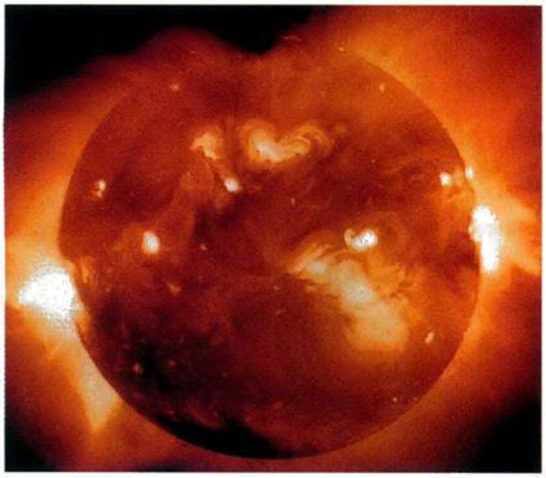
Secrets *of the* Stars

If the 1920s saw the beginnings of modern investigations of galaxies, the 1930s belonged largely to the study of stars. Stars are, of course, one of the fundamental units of the universe. A couple hundred billion of them populate the Milky Way Galaxy alone — including one, the sun, of vital interest to ourselves. They are among the most profoundly beautiful and elegant structures in all nature. But it wasn't until the 1930s that scientists learned how they worked — how they form, remain stable for millions or even billions of years, and then die.

The secrets of the stars awaited the development of atomic physics, a discipline beyond the ken of 19th-century science, which could envisage no mechanisms for supplying energy to a star other than heat released by slow gravitational contraction or by the infall of meteoric matter. Neither of these methods could furnish more than a fraction of the energy needed to sustain a star through its lifetime.

Perhaps the most fundamental question, almost childlike in its simplicity, is: Why do stars shine? It must have been asked for millennia but did not begin to receive a satisfactory answer until the late 1930s. By then, physicists had worked out quantum mechanics — the branch of science concerned with the behavior of atoms and their constituent parts. At the heart of a star, thermonuclear reactions fuse hydrogen atoms into helium nuclei, with a small amount of mass being converted to energy according to Einstein's famous formula $E = mc^2$.

One series of reactions by which this occurs forms the so-called carbon cycle, the details of which were explained in 1938 by Hans Bethe. According to legend, Bethe had resolved to work out the problem on the train from Washington, D. C., where it was being discussed in a meeting, back to Ithaca, New York, before the steward came to announce dinner. He succeeded.


The sun in x-rays (Lockheed Missiles)

Because thermonuclear reactions consume fuel, a star's composition slowly changes. When a star uses up its hydrogen fuel, its core contracts, raising the temperature to the point where helium nuclei can fuse. Helium fuses to carbon, carbon to neon, and neon to oxygen; carbon and oxygen combine to form silicon; oxygen combines with oxygen to make sulfur. At the end, when a massive star begins to convert silicon to iron, it has played its trump card. Forming still heavier atomic nuclei takes more energy than it releases, leaving the star energetically bankrupt. Able to maintain itself for millions or billions of years, the end comes in less than a day. Because thermonuclear reactions are no longer able to resist the relentless force of gravity, the core collapses upon itself. A star like the sun collapses into a small, burned-out, compressed object known as a white dwarf. However, for stars still containing more than 1.4 times as much mass as the sun, even the white dwarf configuration is unstable.

Such massive stars are destined to collapse still further until they have formed a supercompressed object with the density of pure neutrons — a neutron star. This process occurs so rapidly that the rest of the star does not have time to adjust; the overlying shells begin to topple, falling inward upon one another and crashing into the core. The shock wave thus produced carries the lion's share — some 99 percent — of the energy of collapse with it in an explosion so stupefying that in a single blow it forms all the elements heavier than iron. The result is one of the most awesome spectacles in nature — a supernova — in which the outer layers of the collapsing star get ejected into space to form the far-reaching knots, tendrils, and wispy filaments of an expanding gas cloud, such as the Crab Nebula in Taurus (scene of a supernova explosion witnessed in A.D. 1054).

1930s

1930

Clyde Tombaugh discovers Pluto

Subrahmanyan Chandrasekhar determines structure and mass limit of white dwarfs

Bernhard Schmidt invents Schmidt camera

Wolfgang Pauli postulates the existence of the neutrino

Coma Cluster (NASA/STScI)

1931

Karl Jansky detects radio waves from the center of the Milky Way Galaxy

1932

Walter Adams and Theodore Dunham discover thick carbon dioxide atmosphere of Venus

James Chadwick discovers the neutron

1934

Walter Baade and Fritz Zwicky predict supernovae would produce neutron stars

1937

Fritz Zwicky shows that most of the mass in the Coma Cluster of galaxies is invisible

1938

Hans Bethe works out theory of stellar fusion reactions

1940s

1944
Gerard Kuiper discovers atmosphere of Saturn's moon Titan

1946
Martin Ryle discovers first extragalactic radio source (Cygnus A)

1948
Gerard Kuiper discovers Uranus's moon Miranda

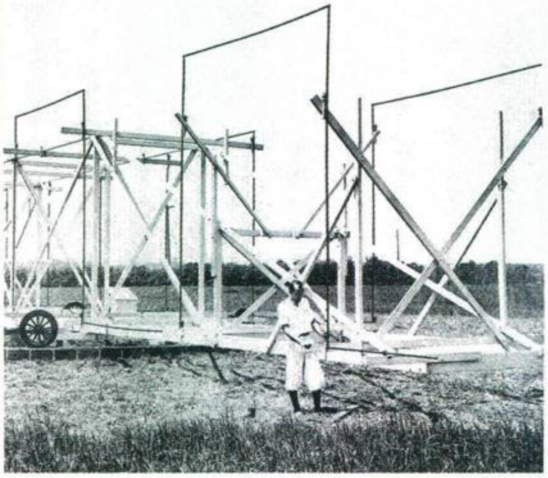
200-inch Hale Telescope dedicated

Ralph Alpher and Robert Herman predict cosmic background radiation

The 200-inch Hale Telescope (Carnegie Observatories)

1949
Gerard Kuiper discovers Neptune's moon Nereid

Expanding *the* Spectrum

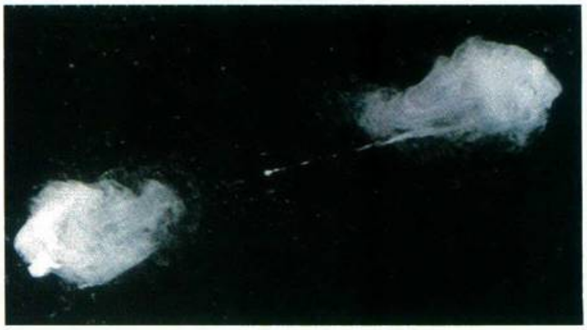

Karl Jansky and first radio telescope (Bell Laboratories)

Throughout most of its history, astronomy meant *optical* astronomy. The only source of information available to astronomers in their studies of the universe was that found in the narrow band of the spectrum known as visible light. Astronomers eagerly collected this light with ever larger lenses and mirrors, recorded it by means of the chemical changes it induced in photographic emulsions, or split it apart and then analyzed it with spectroscopes.

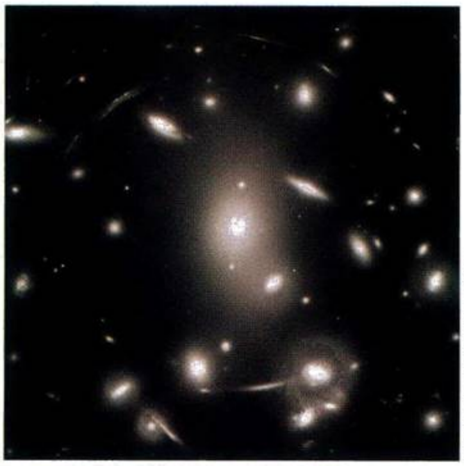
The electromagnetic spectrum is much broader than the visible range alone, however, and other parts of the spectrum — the longer wavelength infrared, microwave, and radio as well as the shorter wavelength ultraviolet, x ray, and gamma ray — contain critical information. Indeed, many of the exotic objects that make up the amazing bestiary of modern astronomy would never have been recognized if astronomers had remained confined to the visible band.

The first foray into this new arena came in 1931, when Bell Telephone Laboratories engineer Karl Jansky serendipitously discovered radio waves emanating from the center of the Milky Way. At the time, Jansky was researching the causes of the static that interferes with radio communications. Using a directional antenna that could be rotated, he sought to identify the sources of such interference. In addition to expected sources, such as the electrical disturbances associated with thunderstorms, he became intrigued by one source that appeared at the same time each day and gained on the sun by four minutes daily, meaning it was fixed relative to the background sky. Eventually, Jansky realized the source lay at the center of the Milky Way Galaxy.

Spurred by the development of radar during World War II, radio astronomy blossomed after the war, especially in Britain. In the mid-1940s, radio astronomy began under Bernard Lovell at Jodrell Bank and Martin Ryle at Cambridge University. Although many radio sources, such as the Crab Nebula and even Jupiter, were identified within our own galaxy, in 1946 Ryle identified the first extragalactic source — the radio galaxy Cygnus A. The brightest radio source outside the Milky Way, Cygnus A was just the first of many other radio sources — including radio galaxies, Seyfert galaxies, BL Lac objects, and quasars — that have since been identified. All of these exotic objects generate stupendous amounts of energy, apparently powered by matter accreting onto supermassive black holes at their centerss.


Radio galaxy Cygnus A (NRAO)

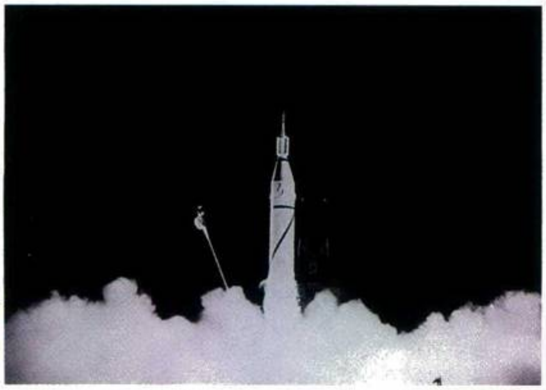
Seeds *of the* Space Race



Abell cluster 2218 (NASA/STScI)

Progress in astronomy has not, of course, taken place in isolation from the great events of our time. The rise of radio astronomy owed much to the development of radar in World War II, and post-war politics — which saw the one-time allies the United States and the Soviet Union facing one another as antagonists — also left their mark. On October 4, 1957, the Soviets shocked the world when they launched the first artificial satellite, Sputnik, atop an intercontinental ballistic missile (ICBM) known as the R-7, which looked "like a mechanical Cossack in billowing pantaloons." Even then, the chief Soviet designer, Sergei Pavlovich Korolev, and his American rival, the German-born Wernher von Braun, were ardently dreaming of ships that would take us to the moon.

The moon became the quintessential goal for the Soviets and Americans as they tried to demonstrate the awesome range and accuracy of their ICBMs. In many ways it was not a scientific goal — there can be little doubt that rockets powerful enough to reach the moon would not have been developed but for the need of the Soviet Union and the United States to prove to one another, in sublimated form, their ability to hurl multi-megaton warheads around the globe and onto each other's soil. It was almost as an afterthought that these weapons were yoked to the purpose of launching satellites and the first lunar probes.



Launch of Explorer 1 (NASA/MSFC)

The Russians had the early successes — on September 14, 1959, at precisely 2 minutes and 24 seconds after midnight (Moscow time), Lunik 2 became the first manmade object to reach the surface of another world when it impacted on the rim of the lunar crater Autolycus. It was followed a month later by the still more magnificent Lunik 3, the first spacecraft to circle around to the moon's farside and obtain photographs of that hitherto unknown region. It showed that the farside had few "seas" compared with the nearside. This was the first trickle in what would become a torrent of information about the moon and planets. The great Race to the Moon had begun — and would culminate in just 10 short years with the first manned landings.

1950s

1950

Jan Oort suggests that long-period comets come from a vast, distant reservoir, now known as the Oort Cloud

1951

Harold Ewan and Edward Purcell discover 21-cm radiation from interstellar hydrogen

1957

Sputnik 1 becomes first artificial satellite

Geoffrey and Margaret Burbidge, William Fowler, and Fred Hoyle describe how stars create heavy elements

1958

Explorer 1 spacecraft discovers Van Allen radiation belts surrounding Earth

George Abell publishes extensive catalog of galaxy clusters

Comet Mrkos arrives from the Oort Cloud (Carnegie Observatories)

1959

Luna 1 spacecraft becomes first to leave Earth's gravity

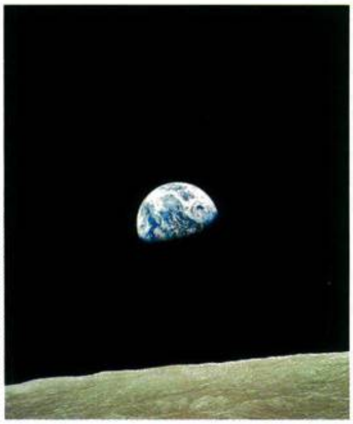
1960s

1961
Yuri Gagarin becomes first man to orbit Earth

1962
John Glenn becomes first American to orbit Earth

Mariner 2 completes first successful planetary flyby (of Venus)

1963
Maarten Schmidt discovers that quasars are extremely energetic objects in the distant universe


Earth rises over the moon (NASA)

1965
Arno Penzias and Robert Wilson discover the cosmic background radiation, the faded echo of the Big Bang

Alexei Leonov goes on first space walk

Mariner 4 flies past Mars

1966
With up to 100,000 meteors per hour, the Leonid shower ranks as the greatest of the century

1967
Jocelyn Bell-Burnell and Antony Hewish discover the first pulsar

First gamma-ray burst detected

1968
Apollo 8 becomes first manned spacecraft to leave Earth's gravity

1969
Apollo 11 lands on the moon

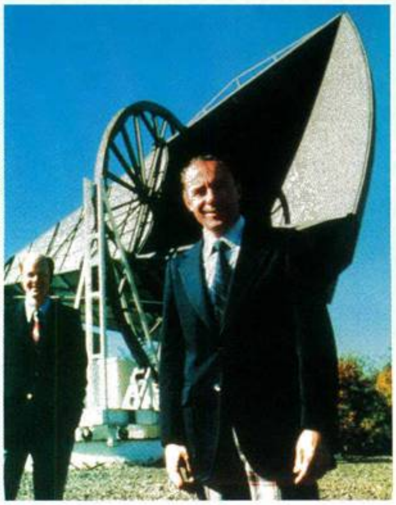
Peace, Love, *and* Background Radiation

Leonid meteor storm of 1966 (Arthur Scott Murrell)

If the universe is expanding, as Edwin Hubble discovered in the late 1920s, it doesn't take an Einstein to imagine what would happen by turning the clock backward. Obviously, there must have been some point, between 10 and 15 billion years ago, when everything existed in a hot, superdense state. In the 1920s, the Belgian Abbé Georges Lemaître introduced an early version of the idea that the universe emerged from such an initial state. It was not until 1950, however, that it was referred to as the "Big Bang" — a term coined by the British astrophysicist Fred Hoyle, who was a critic of the theory and regarded it as inelegant as "a party girl jumping out of a cake."

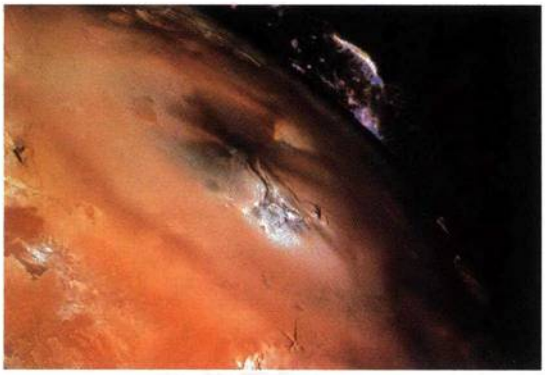
The big bang model would indeed have been a rather speculative affair unless it led to specific predictions. In the 1940s, the Russian-born physicist George Gamow showed that interactions between particles in the hot, superdense early universe would lead to the fusion of hydrogen into helium and produce cosmic abundances of 75 percent hydrogen and 25 percent helium — precisely those actually observed in the oldest stars. Gamow also realized that the seething cauldron of radiation would dim and cool as it was spread out by the expansion of the universe, until the leftover radiation appeared as only a very faint trace in the sky's background. This would be, as it were, the smoking gun of the Big Bang. At the time, no one actually thought to look for it.

Turn the clock forward to 1965, when Bell Laboratories researchers Arno Penzias and Robert Wilson were testing a radio antenna in Holmdel, New Jersey. They discovered an unidentified source of interference consisting of a background of microwave radiation coming uniformly from all areas of the sky. They had no idea what it might be. Others, including a group at Princeton University who were even then planning to search for the cosmic background radiation with their own radio telescope, realized that Penzias and Wilson had unwittingly beaten them to it. Ironically, just a few years earlier, Soviet physicist Igor Novikov wrote a paper that not only predicted the existence of the microwave background but also suggested that the Holmdel antenna would be the best instrument for finding it. Unfortunately, the commerce in ideas between East and West was then at its lowest ebb, and Penzias and Wilson never heard of Novikov's paper.


Penzias and Wilson with the Holmdel antenna (Bell Laboratories)

The microwave background radiation was the grail of modern cosmology — an ancient relic of creation representing the cooled fireball of radiation from the Big Bang itself. At low resolution, the background appears remarkably smooth and uniform. Yet at high resolution, small ripples appear that are remnants of quantum fluctuations that took place when the entire universe was smaller than a potato. These were imaged in the famous map made from observations by the Cosmic Background Explorer satellite of the early 1990s. It is sobering to think that these ripples, magnified greatly by the expansion of the universe, represent the seeds of the largest known structures in the universe — the superclusters of galaxies.

Epic Voyages *of* Discovery

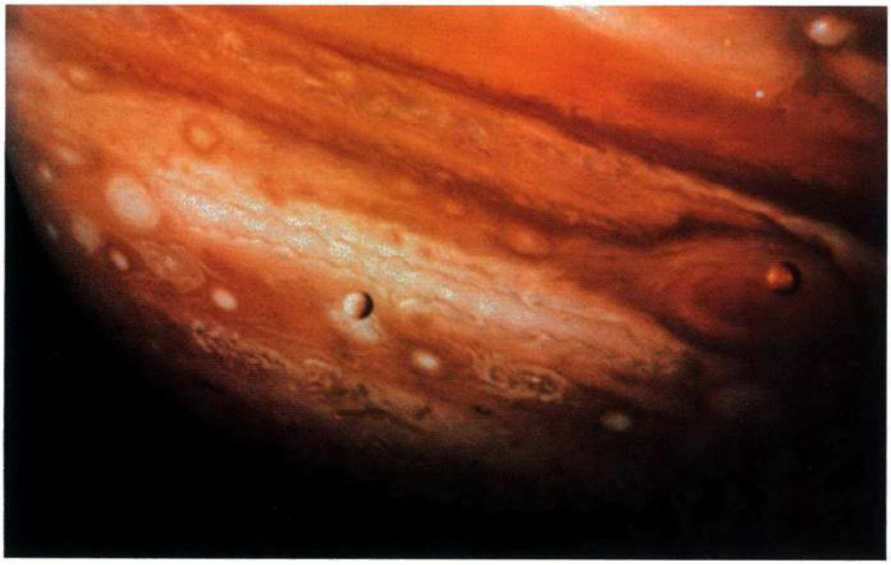


Io's erupting volcanos (NASA/JPL)

After the manned landings on the moon of the late 1960s — events of far greater public note if not as scientifically important as the discovery of the Big Bang's remnant radiation — the general populace seemed to lose interest in the exploration of space. Following the flights of Mariners 4, 6, and 7 — which swept past Mars in the mid- to late 1960s and revealed the martian surface to be cratered heavily like the moon's — politicians nearly canceled the Viking lander missions. Those missions were ultimately rescued by Mariner 9, which went into orbit around Mars in 1971 and showed the Red Planet to be a world of volcanos, gigantic canyons, and dry riverbeds. Mars was not another moon — nor, for that matter, another Earth as had long been supposed — it was a world all its own.

It's difficult for most of us to realize that for generations, the planets were no more than blurry blobs in the eyepiece of the telescope, worlds too poorly seen and imaged to be understood. The first adequate maps of Mars didn't come until after Mariner 9, and the outer planets were first seen in riveting detail by the two Voyager spacecraft launched in 1977. (They were also near casualties of the budget process.) The Voyagers were grand missions on the scale of the great 15th-century explorations of Diaz, Balboa, and Columbus, or the daring around-the-world voyage of Magellan. They led to the discovery of a wispy thin ring around Jupiter; to the nearly continual eruptions of its moon Io, the most volcanically active world in the solar system; and provided the first hints of a possible subsurface ocean on the moon Europa. Voyager also showed magnificent structures in the rings of Saturn; revealed Uranus and its geologically complex moon Miranda; and imaged stormy Neptune with its large, volcanically active moon Triton as a pair of beautiful crescents when the spacecraft looked back at them as it continued on its path out of the solar system.

But of the many gripping images taken by these spacecraft, none, perhaps, was more enlightening than that of the entire inner solar system taken by Voyager 2. This image shows Earth — the seat, the home of humans — as a single illuminated pixel, almost swamped by the glare of the sun. As the late Carl Sagan put it, Earth was simply a pale blue dot.



Voyager captures Jupiter and two moons (NASA)

1970s

1971

Mariner 9 goes into orbit around Mars

Mars 3 craft soft-lands on Mars

1973

Astronomy magazine founded

Pioneer 10 flies past Jupiter

1974

Mariner 10 flies past Mercury

Stephen Hawking shows that black holes can slowly radiate energy

Russell Hulse and Joseph Taylor discover a binary pulsar, with which they prove existence of gravitational waves

Viking lander on Mars's surface (NASA/JPL)

1976

Vikings 1 and 2 land on Mars

Comet West glows at its brightest

1977

The rings of Uranus are discovered

1978

James Christy discovers Pluto's moon, Charon

1979

Voyagers 1 and 2 fly past Jupiter

Pioneer 11 flies past Saturn

First gravitational lens sighted

1980s

1980

Voyager 1 flies past Saturn

Luis and Walter Alvarez propose that a large impact caused a mass extinction 65 million years ago

1981

First launch of the space shuttle

Voyager 2 flies past Saturn

Alan Guth publishes his idea of an inflationary universe

1982

The first millisecond pulsar is discovered

Supernova 1987A (European Southern Observatory)

1983

Pioneer 10 leaves the solar system

1986

Voyager 2 flies past Uranus

The space shuttle Challenger explodes, killing its crew

First component of the Soviet Mir space station launched

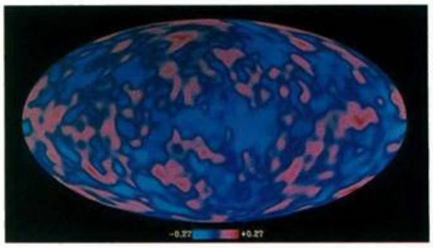
1987

Supernova 1987A explodes, the brightest supernova in nearly 400 years

1989

Voyager 2 flies past Neptune

A Twist *to the* Big Bang



The microwave background (NASA)

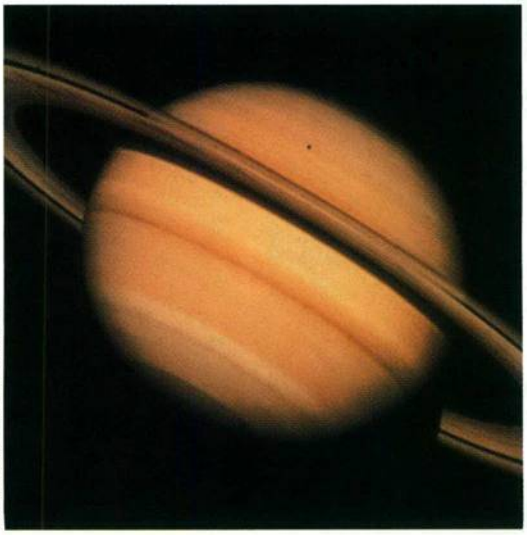
Physicists have played a key role throughout the history of 20th-century astronomy. You need look no further than Albert Einstein's theories on the nature of space and time or Hans Bethe's calculations showing that nuclear fusion reactions provide the energy stars need to shine to realize how physics has fundamentally changed the way we perceive the universe.

In the early 1980s, Alan Guth (then a particle physicist at the Stanford Linear Accelerator Center) helped strengthen the link between physics and astronomy when he proposed his inflationary theory of the early universe. Guth became intrigued by cosmology after hearing a talk in 1978 by Princeton cosmologist Robert Dicke. He was particularly impressed by some of the arbitrary initial conditions needed in the big bang theory.

Guth understood the remarkable power of the big bang theory in describing how the universe came into existence. The theory neatly explains the universe's expansion as the aftermath of a titanic "explosion" — the Big Bang — that marked the birth of the universe. Even more impressive, the big bang theory correctly predicted the relative amounts of the two most abundant elements in the universe, hydrogen and helium. The coup de grâce came in the mid-1960s, when Arno Penzias and Robert Wilson discovered that the universe was filled with microwave radiation, the fading echo of the Big Bang.

For all its successes, the big bang model was too simple to be the final answer. Two problems loomed particularly large. First, the microwave background radiation appears remarkably constant across the whole sky. The only way that the standard model can explain this is if the entire universe started at the same temperature. There simply was no way for distant parts of the universe to "communicate" with one another and reach a uniform temperature. The second problem is that the universe appears nearly flat, meaning that the overall structure of space-time has little if any curvature.

Guth looked at the early universe as an arena where the then new Grand Unified Theories of physics, which attempt to unify the electromagnetic force with the strong and weak nuclear forces, could be put to the test. He envisioned the universe undergoing a phase of extraordinarily rapid expansion, in which the universe inflated by roughly a million trillion trillion times in a tiny fraction of a second about 10^{-35} second after the Big Bang. Prior to this inflationary period, the universe would have been small enough to reach a uniform temperature, and the expansion itself would have driven the universe to near perfect flatness.

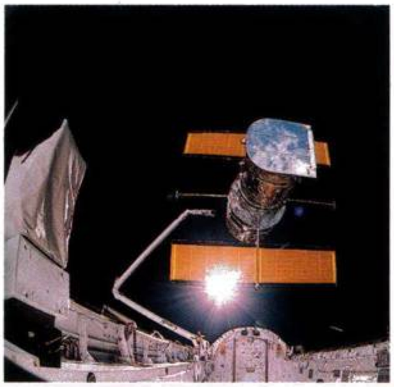


Voyager shoots Saturn (NASA/JPL)

Although Guth's original idea had some holes, modifications developed by Andrei Linde, Paul Steinhardt, Andrew Albrecht, and others ironed them out. When the Cosmic Background Explorer detected tiny ripples in the microwave background in the early 1990s, astronomers interpreted them as imprints inflation left on the fabric of space-time. The discovery of the ripples marked the first prediction made by inflation to be observed and helped solidify its acceptance.

Planets *by the* Dozen

Are we alone in the universe? This is perhaps the most haunting question of all those we can ask upon looking into the starry heavens; a question that has remained — despite a flurry of excitement spawned by a martian meteorite — unanswered. But we are, at century's end, closer to an answer than we have ever been. Astronomers have worked out many of the details describing how a swirling cloud of gas and dust gives rise to planets, and the processes by which the chemistry on some of those worlds — those such as Earth with liquid water on their surfaces — may go on to form primitive and then intelligent life.



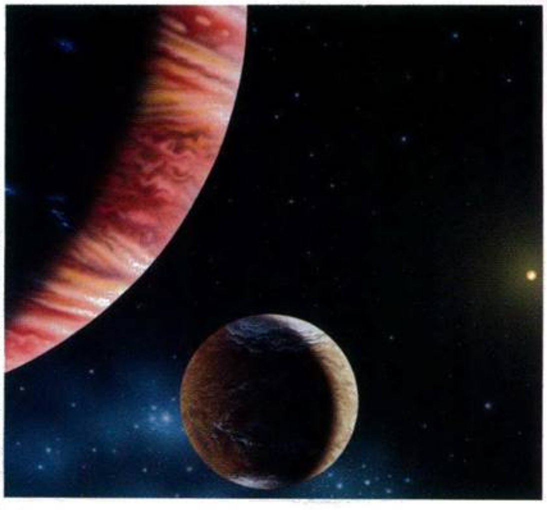
Hubble being deployed (NASA)

Are there other worlds in space, retinues to accompany the other stars as our planetary system accompanies the sun? For a long time they were hopelessly elusive. Until the 1990s, the only planet discovered in the 20th century was Pluto — the solar system's most distant major member, captured in 1930 by Clyde Tombaugh at Lowell Observatory. And even it ended the century being threatened with demotion from its planetary status.

But what of other planets surrounding other suns? They could be revealed by their slight gravitational tugs on their parent stars. For a long time, astronomers expected that when and if such planets finally did turn up, they would be counterparts to those of our own system — including Jupiter-size planets at roughly jovian distances from their stars. That was the thinking of Geoffrey Marcy and Paul Butler, the San Francisco State University astronomers who began looking for extrasolar planets in 1987 with the 120-inch Shane Telescope at Lick Observatory.

They were as surprised as everyone else when in 1995 Swiss astronomers Michael Mayor and Didier Queloz announced the discovery of a planet near the star 51 Pegasi. This proved to be a world completely different from the theorists' expectations: It was a giant planet, at least half as massive as Jupiter, orbiting closer to its star than Mercury is to the sun. Marcy and Butler needed only five days to confirm that Mayor and Queloz's planet was real and soon turned up a host of other extrasolar planets surrounding still other stars from their own data. By June 1999, approximately 20 extrasolar planets had been discovered, ranging in size from about half as large as Jupiter to more than five times larger.

Strangely enough, nearly half the systems discovered so far consist of giant planets traveling in highly eccentric orbits. Such planets would doom any Earth-like planet unfortunate enough to belong to the same system by tossing it clear of its orbit. By contrast, the planets in our own solar system occupy stable, almost circular orbits, which are less susceptible to the extreme gravitational perturbations that rule the wilder but apparently more common systems. It seems likely that only tame systems such as ours would be compatible with life — or at any rate with the more advanced forms of it. From this point of view, it seems that most of the worlds in space have been created, more or less, in vain. They have not been, and never will be, abodes of life. A startling conclusion to end the century on.



Planets around the star 47 Ursae Majoris (Lynette Cook)

1990s

1990
Hubble Space Telescope deployed

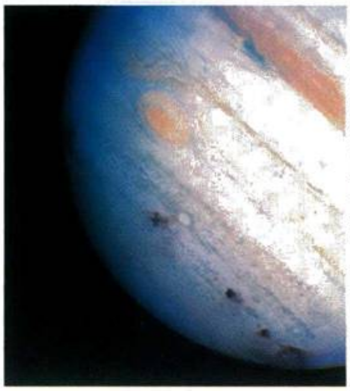
Magellan radar mapper arrives at Venus

1991
Compton Gamma Ray Observatory deployed

1992
Astronomers announce discovery of tiny ripples in the cosmic background radiation, the seeds from which the largest structures formed

David Jewitt and Jane Luu discover the first member of the Kuiper Belt

Aleksander Wolszczan and Dale Frail discover two planets orbiting a pulsar



Comet Shoemaker-Levy 9 hits Jupiter (NASA/STScI)

1993
The 10-meter Keck Telescope opens

1994
Comet Shoemaker-Levy 9 smashes into Jupiter

1995
Michel Mayor and Didier Queloz discover the first extrasolar planet orbiting a sunlike star

The Galileo spacecraft arrives at Jupiter

The first brown dwarfs are discovered

1997
Gamma-ray bursters are shown to lie in distant galaxies, making them the most energetic objects in the universe

1998
Astronomers announce evidence that the expansion of the universe is accelerating

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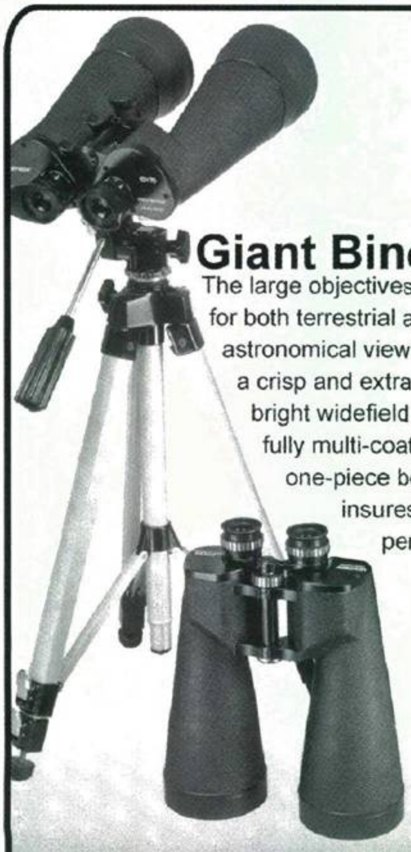

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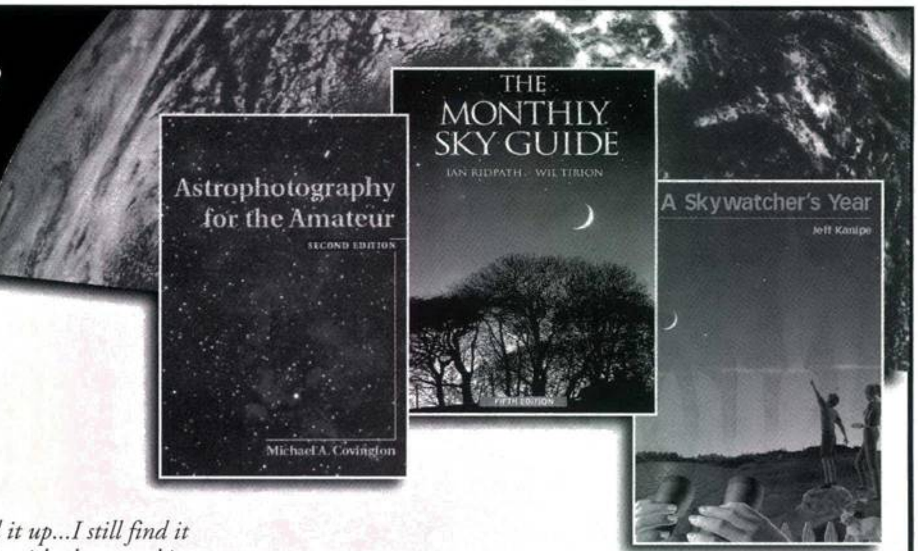

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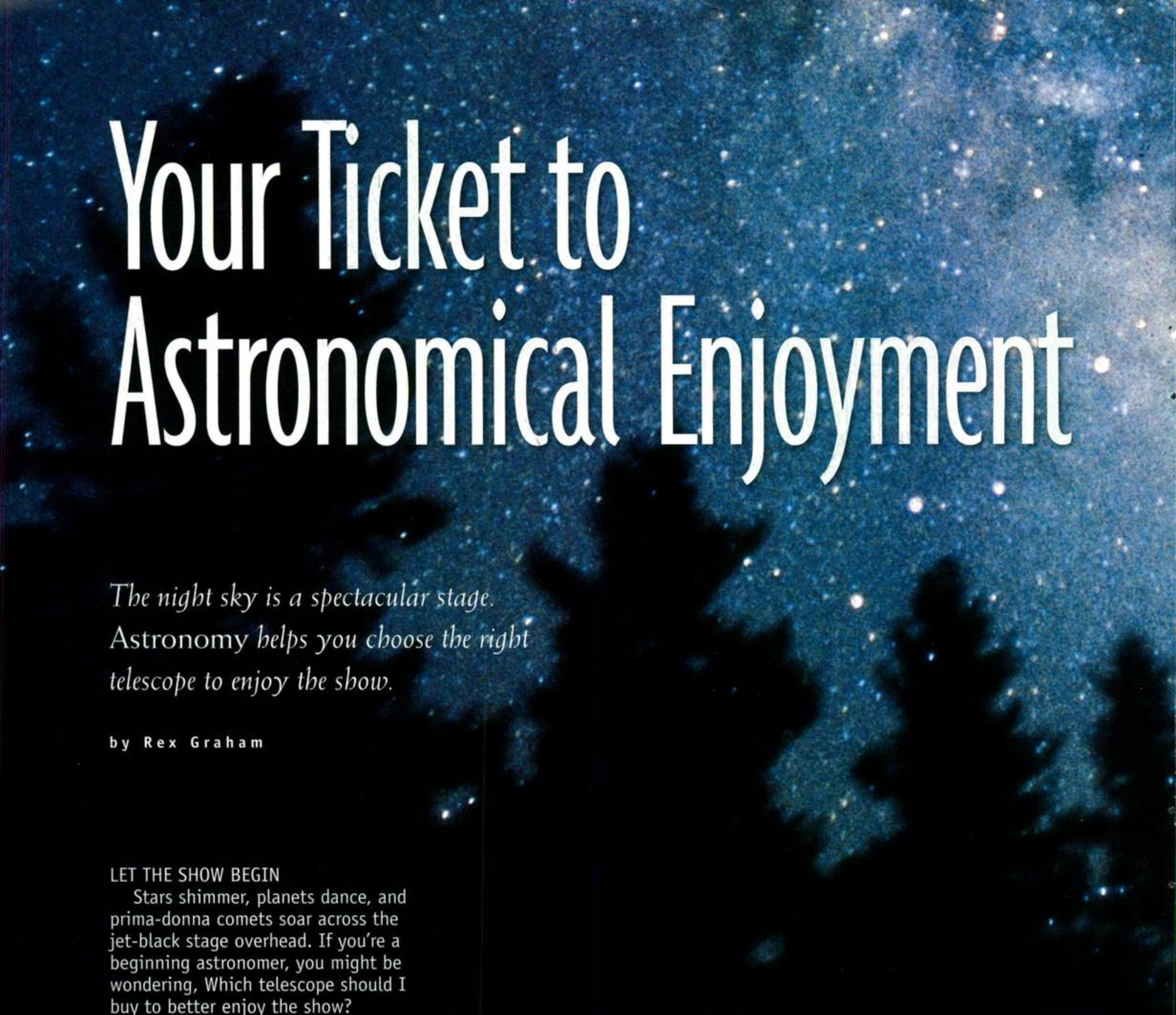


Your Ticket to Astronomical Enjoyment

The night sky is a spectacular stage. Astronomy *helps you choose the right telescope to enjoy the show.*

by Rex Graham

LET THE SHOW BEGIN

Stars shimmer, planets dance, and prima-donna comets soar across the jet-black stage overhead. If you're a beginning astronomer, you might be wondering, Which telescope should I buy to better enjoy the show?

The answer is not simple. It depends on where you live, your interest level, and how much money you want to spend. The truth is that gazing up with the naked eye or with binoculars can be breathtaking. But if you're familiar with the constellations and can discern Jupiter from a star, you are probably yearning for more.

Some big reflector telescopes cost about as much as some small refractors. The choices seem endless. Relax. The following guide is meant to help.

Here you will discover which objects you can see best with your naked eye, binoculars, and various types of telescopes. Your options may exceed what you thought possible, and this guide is intended to help you get the most for your money.

COMETS: They arrive unexpectedly like a favorite friend. If you witnessed the spectacular Comet Hale-Bopp in 1997, you know what we mean. No new Hale-Bopps are expected in 2000, but you can see many comets in future years as they approach perihelion, the innermost points of their orbits around the sun.

Gary L. Meador

METEORS: Even though meteoroids, high-speed visitors from space, usually are the size of sand grains, they vaporize into big streaks of light called meteors. Meteoroids big enough to hit Earth's surface are called meteorites. Meteor showers occur about 11 times per year as our planet passes into streams of particles cast off by comets.

Keyly Garrison

Milky Way photo by Jerry Schad

NAKED EYES ON THE SKIES

Naked-eye observing offers a rich vista of beautiful sights. Viewing the moon, planets, and colorful aurorae requires little more than clear skies and simply looking up. This is where most amateur astronomers begin. Naked-eye observing costs nothing and by learning your way around the night sky, you will sharpen your lifelong observational skills.

In dark locations, the sky is smothered in stars. The most spectacular sight is our view of our Milky Way Galaxy from the inside. It is 100,000 light-years across and contains 200 billion stars and a rich assortment of astronomical objects.

Star maps in *Explore the Universe* and in monthly issues of *Astronomy* will help you locate asteroids, comets, planets, stars, galaxies, and nebulae. They also keep you up-to-date on planetary conjunctions, meteor showers, solar and lunar eclipses, and many other astronomical events.

THE MOON: When it's up, it's always the brightest object in the night sky. The full moon provides an ample view of its round, pockmarked face. But long shadows present during the side-lit phases of gibbous, quarter, and crescent moons accentuate features such as craters and ancient lava flows known as maria.

Jim Primrose

PLANETS: The brightest planets — Mercury, Venus, Mars, Jupiter, and Saturn — increase and decrease in visibility, depending on their distance from the sun and from Earth. A good time to view Mars and the other outer planets is when they are opposite the sun in the sky — at opposition — or overhead and visible all night.

Bill Hutchinson

Astronomy: Jim Forbes

BINOCULAR VIEW

One of the smallest, least expensive, and most portable pieces of astronomical equipment you can buy is a pair of binoculars. A quality set will provide great, wide-field views of everything from the bright moon to dim nebulae scattered like jelly fish along the Milky Way. With typical binoculars, you can see objects as faint as magnitude 11.

Binoculars are classified by their magnifying power and the diameter of their lenses. So a pair of 5x35mm binoculars will magnify objects five times through its 35-millimeter-diameter lenses. A pair of 7x50mm binoculars will magnify objects seven times through 50-millimeter-diameter lenses. You can purchase a pair of 7x50mm binoculars for as little as $50 or as much as $1,400. They can weigh less than two pounds, which makes them extremely portable. However, be aware that hand-holding the binoculars will subject them to a certain amount of wobble and may cause a little muscle strain.

You can relieve wobble and strain by purchasing a binocular mount. It might not be necessary for 7x50s but is a definite requirement for those in the 20x80mm range. These models are as big as car headlights. Binocular mounts range in price between about $200 and $3,500. For more details on buying binoculars, check out "*Astronomy*'s 2000 Buyer's Guide to Telescopes and Binoculars" by Phil Harrington on page 74.

THE MAIN ATTRACTION

At some point you may be ready for a telescope. Deciding which one to buy is not easy. An array of equipment awaits you in different sizes, shapes, and prices. Neither the most inexpensive nor the biggest may be right in the long run. For example, a 10-inch reflector retailing for $750 shows more deep-sky objects than a 3-inch refractor retailing for $1,500, but the big reflector is heavier. Near a big city, the reflector may not be the best choice because its light-gathering power makes it more sensitive to interference from light pollution.

Before you buy, also consider what you will observe. Are you fascinated with the moon or planets? Maybe you fancy observing far-away galaxies or the glow of distant nebulae. Or perhaps the idea of comet chasing or asteroid hunting gives you a thrill. Whatever you like, there's a telescope for you.

We've ranked the major types of scopes with a "Wow!" factor. (Our lowest "Wow!" rating gets one star, the highest gets five.) We suggest a telescope with highest "Wow!" factor that you can afford. The guide includes cost estimates and rankings of portability, ease of setup, and ease of use. Don't summon the plastic from your wallet or call a manufacturer's toll-free telephone number until you have taken time to read this and pondered your choices carefully:

Astronomy: Jim Forbes

SMALL 'BARGAIN' REFRACTORS

(2- to 3-inch lens)
Price range: $100 – $200
Portability: ★★★★★
Ease of setup: ★★★★★
Ease of use: ★★

Wow! factor for...
moon: ★★
comets: ★
double stars: ★
galaxies and nebulae: ★
planets: ★

The shortcomings of a bargain refractor begin with the most important part — the objective lens. The sticker may advertise the lens as a "60mm" (2.4 inches), but it's probably smaller. Inexpensive telescopes rely on inexpensive optics. Low quality lenses produce distorted images, especially on their outer edges. To get around this, some manufacturers install a baffle, a doughnut-shaped disk, inside the tube to block light from passing through the inadequate outer rim of the lens. This reduction in light produces a dim image.

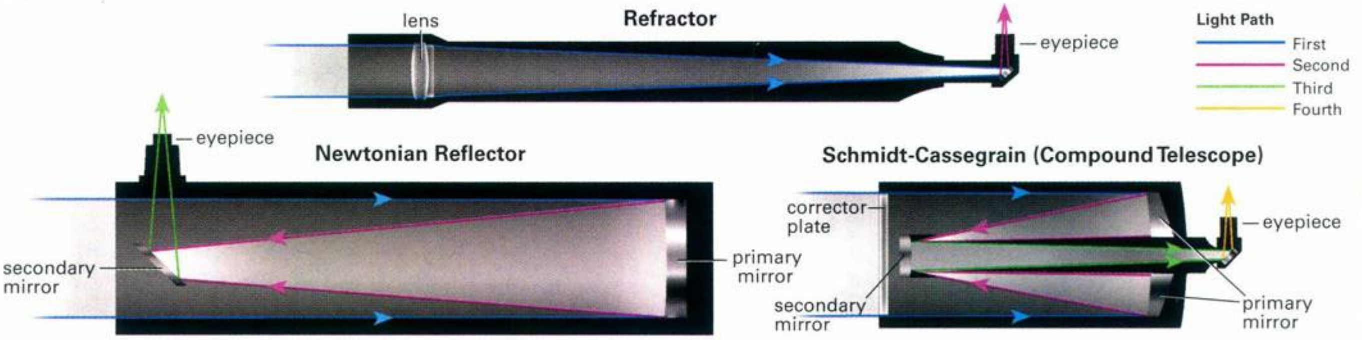
Some manufacturer advertisements will promote "magnification," to impress the uninitiated. This is merely a gimmick. You can improve any telescope's magnification with an eyepiece. And finally, bargain telescopes come equipped with flimsy tripods. Even if you could see bright images through the lens, they would

GALAXIES: The naked-eye smudge of the Andromeda Galaxy begins to look like a real galaxy as seen with binoculars. Hunt through Triangulum for M33, another spiral in our Local Group of galaxies. Virgo is home to several bright ellipticals. With binoculars you can see hundreds of galaxies too dim to see otherwise. D. B. Jamison

STARS AND CONSTELLATIONS: You can see about 6,000 stars with the naked eye, but with binoculars constellations such as the Big Dipper suddenly brim with them. Most look white, however Arcturus, a magnitude 0.0 star off the Big Dipper's handle in Boötes, is orange. Betelgeuse, a magnitude 0.5 star in Orion, is orange-red. Alan Dyer

THE MOON: Mountains and craters pop into view through binoculars. Crater rays of debris radiate from the largest craters, Tycho and Copernicus, during full moons. During phases, scan the uneven "terminator" line between light and darkness as it moves about 0.5° per hour across the surface. John Chumack

HOW TELESCOPES WORK


Refractor
lens
eyepiece
Light Path
First
Second
Third
Fourth
Newtonian Reflector
eyepiece
secondary mirror
primary mirror
Schmidt-Cassegrain (Compound Telescope)
corrector plate
secondary mirror
eyepiece
primary mirror

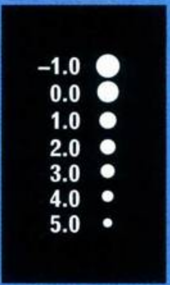
Astronomy: Elisabeth Rowan

The Moon Walace Fernando Neves

wobble in the eyepiece on the unsteady mount. Most people quickly retire these scopes to the basement or unload them at garage sales.

If you have only $99.95 to spend, buy binoculars.

MAGNITUDE: LESS IS MORE


-1.0
0.0
1.0
2.0
3.0
4.0
5.0

Astronomy employs an old convention for rating the brightness of astronomical objects. Similar to golf in which the best scores are the smallest ones, the brightest objects in the sky have the lowest values on a scale of magnitudes. For example, the brilliant red star Betelgeuse, in Orion, glows at magnitude 0, while the much brighter star Sirius shines at magnitude -1.5. Venus, the brightest planet, glows at about magnitude -4, while the moon, the most dazzling orb in the night sky, gleams at magnitude -12.7 when full. Each magnitude is 2.5 times brighter than the next higher whole number, and in dark-sky locations, most people can see objects of magnitude 6 or brighter without optical aid. Under extraordinary conditions, the faintest stars visible to the naked eye are magnitude 7.

Astronomy: Jim Forbes

SMALL ACHROMATIC REFRACTORS

(3- to 4-inch lens)
Price range: $200 – $800
Portability: ★★★★★
Ease of setup: ★★★
Ease of use: ★★★

Wow! factor for...
moon: ★★★★★
comets: ★★
double stars: ★★★★
galaxies and nebulae: ★★
planets: ★★★★

SMALL APOCHROMATIC REFRACTORS

(4- to 5-inch lens)
Price range: $700 – $10,000
Portability: ★★★★
Ease of setup: ★★★★★
Ease of use: ★★★★

Wow! factor for...
moon: ★★★★★
comets: ★★★★
double stars: ★★★★
galaxies and nebulae: ★★★
planets: ★★★★

Good “beginner” scopes open a truly marvelous world of planets, double stars, galaxies, nebulae, and several hundred deep-sky objects. The objective lens, eyepieces, and mounts are far superior to those that come with the bargain refractors. Typically, these telescopes come in two models: achromatic and apochromatic.

An achromatic scope contains two lenses that focus two colors of the visible-light spectrum to a focal point.

Astronomy: Jim Forbes

SMALL-APERTURE REFLECTORS

(3 to 6 inches)
Price range: $120 – $1,000
Portability: ★★★★★
Ease of setup: ★★★★
Ease of use: ★★★★⯪

Wow! factor for...
moon: ★★★★★
comets: ★★
double stars: ★★★★
galaxies and nebulae: ★★
planets: ★★★★

A 6-inch reflector costs about the same as an 80mm (3.2-inch) refractor, but the refractor lens will produce sharper images of bright nearby objects. However, a 6-inch reflector collects 3.5 times more light than an 80mm refractor, which enables the reflector to capture more distant objects. A Dobsonian reflector rests in an inexpensive mount that pivots with a soft tug. A Newtonian reflector sits on a equatorial mount you must align.

Astronomy: Jim Forbes

SMALL-APERTURE COMPOUND TELESCOPES

(3.5- to 5-inch primary mirror)
Price range: $500 – $4,300
Portability: ★★★★★
Ease of setup: ★★★★
Ease of use: ★★★⯪

Wow! factor for...
moon: ★★★★★
comets: ★★
double stars: ★★★
galaxies and nebulae: ★★
planets: ★★★

MEDIUM-APERTURE COMPOUND TELESCOPES

(6- to 8-inch primary mirror)
Price range: $1,000 – $4,000
Portability: ★★★★
Ease of setup: ★★★★
Ease of use: ★★★★⯪

Wow! factor for...
moon: ★★★★★
comets: ★★★
double stars: ★★★★
galaxies and nebulae: ★★★
planets: ★★★

Compound telescopes are based on a novel design that has led to their popularity. Some would say that compound telescopes offer the best of both worlds: the large light-gathering power of a reflector combined with the portability of a refractor. Types of

Saturn Alessandro Cipolat

Jupiter Tom Endemann

M11 (open cluster in Scutum) Mace Hooley

The views provided by the smallest achromatic refractors are equivalent to those seen with a high-quality pair of mounted 10x80mm binoculars. An apochromatic refractor has three lenses designed to focus three or more colors to a focal point. The apochromats are the champions in terms of image quality. Control knobs on both of these types of telescopes also allow the user to keep any object in the field of view.

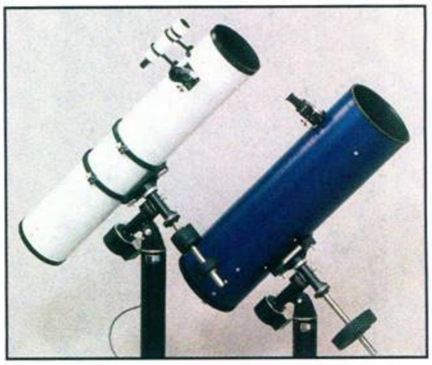
Caution: If these telescopes get your astronomical blood boiling, you'll probably want to step up to a better piece of equipment within a year or two. You are not alone. Still, you can keep this scope or give it to a friend.

MEDIUM-APERTURE REFLECTORS
(8 to 14 inches)
Price range: $400 – $14,000
Portability: ★★★
Ease of setup: ★★★
Ease of use: ★★★★½

Wow! factor for...
moon: ★★★★★
comets: ★★★★
double stars: ★★★★
galaxies and nebulae: ★★★★
planets: ★★★★

With these scopes spiral galaxy M101 comes alive. It is easy to spend $700 to $1,000 or more for a medium-sized reflector. The money will buy you joy.

However, light pollution interferes with a medium-sized reflector's views. If clear, clean, calm, and dark-sky conditions don't occur in your backyard, you will haul this scope to a dark-sky site. Portability is important. It's a chore for one person to set up and take down a 14-inch reflector.



Astronomy: Jim Forbes

M42 (Orion Nebula) Patrick McCullough

M37 (open cluster in Auriga) Pat McCullough

Sunspots George Valachovic

compound telescopes include Schmidt-Cassegrains, Maksutov-Cassegrains, and Maksutov-Newtonians. All of them are popular among city dwellers who travel to avoid light pollution.

A compound telescope uses a so-called corrector plate at the front end, which corrects the image cast by a spherically curved primary mirror at the base of the telescope tube. A convex secondary mirror reflects the light to a focal point at the scope's back end. The more complicated internal design allows for a more compact tube, cutting in half the length of a standard reflector. This lightens the scope, makes it easier to transport, and preserves a reflector's advantages.

Astronomy: Jim Forbes

LARGE-APERTURE COMPOUND TELESCOPES

(9- to 16-inch primary mirror)
Price range: $1,700 – $20,000 or more
Portability: ★½
Ease of setup: ★★
Ease of use: ★★★

Wow! factor for...
moon: ★★★★
comets: ★★★★
double stars: ★★★★
galaxies and nebulae: ★★★★
planets: ★★★★

As compound telescopes double in aperture their light-gathering power quadruples. The results at the eyepiece are exhilarating. The moon, planets, and dozens of planetary nebulae and galaxies become more colorful and beautiful with larger and larger compound telescopes.

The larger compound telescopes are heavier and are less likely to fit into some cars. The main drawback is price. A compound scope costs more than a Newtonian reflector of the same size.

Astronomy: Jim Forbes

LARGE-APERTURE REFLECTORS

(15 inches or more)
Price range: $1,200 – $36,000
Portability: ★★
Ease of setup: ★½
Ease of use: ★★★½

Wow! factor for...
moon: ★★★★
comets: ★★★★★
double stars: ★★★★★
galaxies and nebulae: ★★★★★
planets: ★★★★★

For many observers, the first view through the eyepiece of one of these telescopes is akin to a stunning religious experience. Suddenly, the observer is transported to space. Nebulae appear big and bright and even show subtle hues of color. Asteroids, comets, galaxies, variable stars, and other astronomical objects hover like ghosts in the eyepiece.

Unfortunately, you can't easily haul a large reflector in a standard-sized car. Get a trailer to move one of these monsters and ask some friends to help with the one-hour setup. Dark-sky locations are required because light pollution becomes so bright it obscures the view. Owning one of these scopes is a lifestyle.

Astronomy: Jim Forbes

LARGE ACHROMATIC REFRACTORS

(5- to 8-inch lens)
Price range: $800 – $3,200
Portability: ★★ – ★★★★
Ease of setup: ★★★½
Ease of use: ★★★★

Wow! factor for...
moon: ★★★★★
comets: ★★★★
double stars: ★★★★★
galaxies and nebulae: ★★★
planets: ★★★★★

LARGE APOCHROMATIC REFRACTORS

(6- to 8-inch lens)
Price range: $5,000 – $27,000 and up
Portability: ★★
Ease of setup: ★★
Ease of use: ★★★★

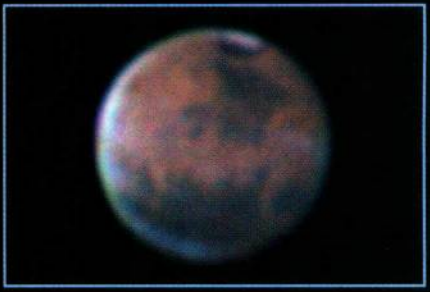
Wow! factor for...
moon: ★★★★★
comets: ★★★★
double stars: ★★★★★
galaxies and nebulae: ★★★
planets: ★★★★★

After you have "Oohed" while looking through a big reflector, try a large refractor. Although they don't collect anywhere near the amount of light as a large reflector, the finely crafted lenses provide more-stunning views.

Razor-sharp stars will appear to

The Sun (with Hα filter) D. Lammon

Galaxies NGC 4438 and 4435 Kim Zussman

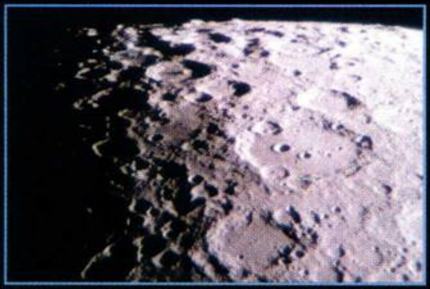

Mars Marizio Di Sciullo

Saturn Occultation Emergence Chris Cook

Galaxy Cluster in Perseus Kim Zussman

Comet Hyakutake Alberto Levy

M31 (Andromeda Galaxy) Jerry Lodriguss


Lunar Craters Philip A. Toren

Seagull Nebula Bill and Sally Fletcher

hover near the spider-web wisps of planetary nebulae on inky-black backgrounds. Many stars that lack color in reflectors suddenly look yellow, blue, or red with the pinpoint precision of the images. Large refractors are also great for taking astrophotographs. An added autoguider will keep the telescope on target by using a reference star as a guide. Demand for these scopes has become so high that manufacturers have waiting lists of hopeful buyers. 🅰

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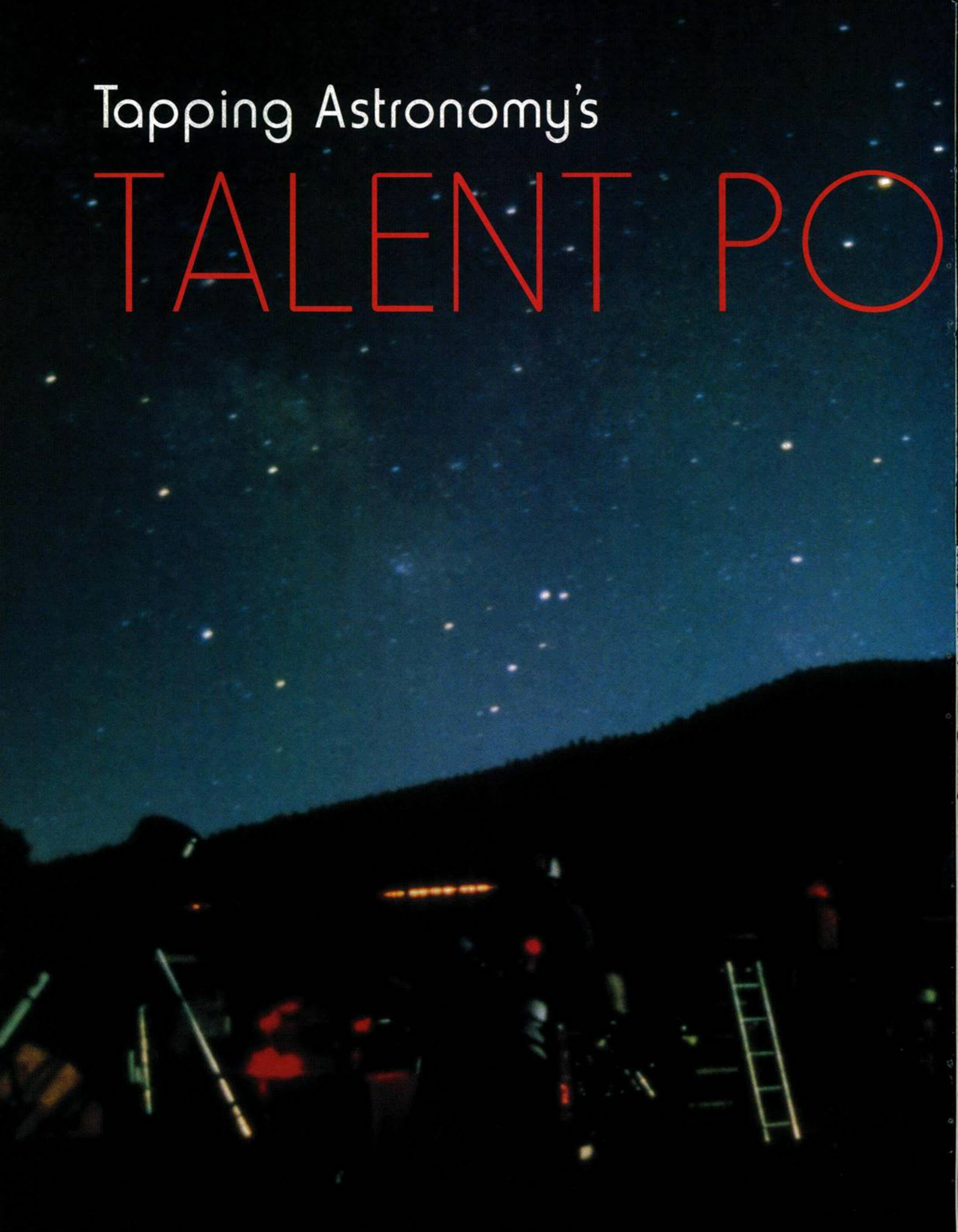
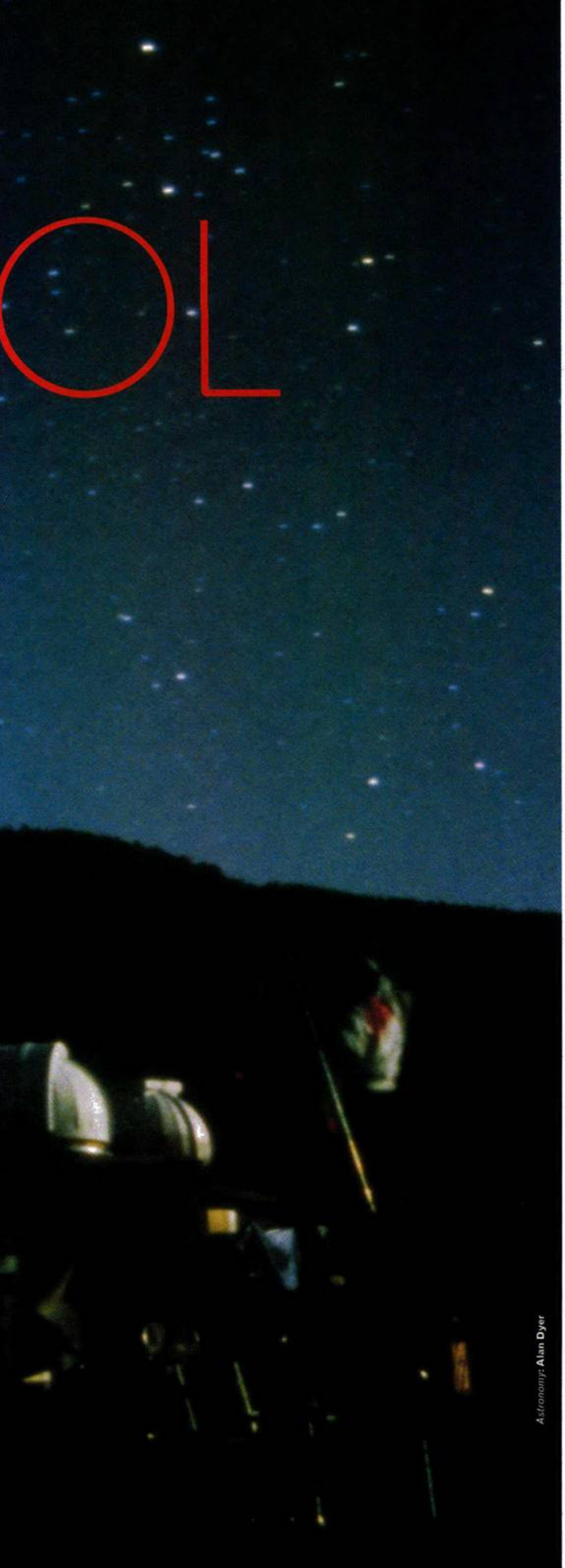
Tapping Astronomy's TALENT PO





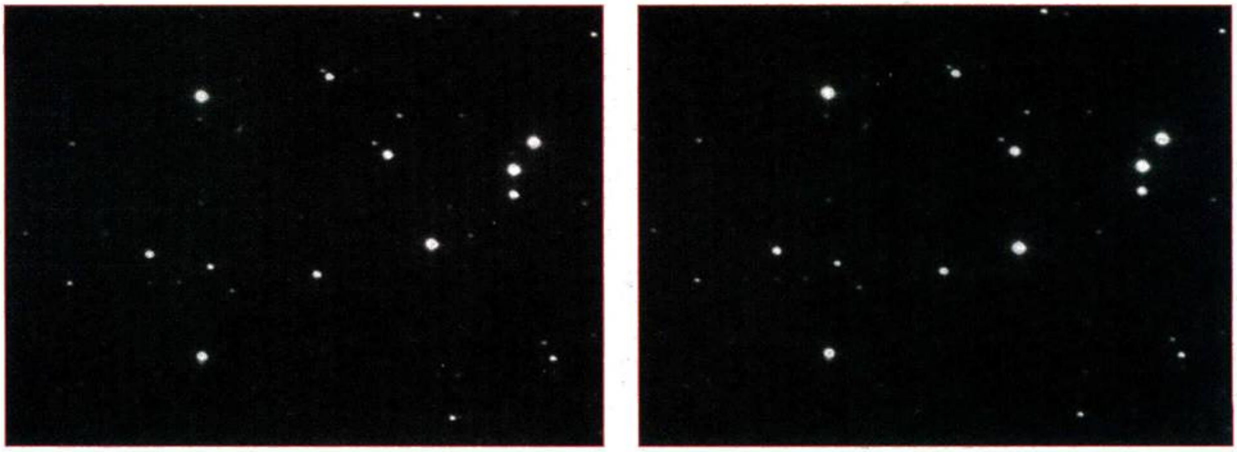
Astronomy: Alan Dyer

From bagging asteroids to hunting supernovae, hundreds of amateur astronomers contribute to science from their backyards.

by Tracy Staedter

Two hundred miles north of the urban glow over Sydney, Australian amateur astronomer Gordon Garradd stands alone under an arena of stars. He looks toward the constellation Pyxis, where the distant asteroid 1992 BL_2 supposedly tumbles along its elliptical orbit around the sun. Discovered in 1992 and viewed for another month, the elusive interloper has not been seen since. Tonight, Garradd hopes to change that.

Retrieving a computer from his mobile home — the only building at Loomberah Observatory, his hilltop property — he heads for the orchard in the valley. An old four-wheel-drive truck waits silently with an 18-inch (45 cm) Newtonian reflector perched in the flatbed. Garradd approaches surefootedly in the darkness of the new moon, having observed from this spot hundreds of times before. At the truck, he sets down the computer and plugs it into a battery bank charged by solar panels. It takes the CCD camera 20 minutes to cool down to operating temperatures. After centering the barrel of his telescope on the approximate position of the asteroid, Garradd clicks a button on the computer's screen that controls the camera's shutter. Over the course of the night, he will take several hundred 5- to 10-second exposures. If 1992 BL_2 is there, he will notice it as an inconspicuous speck that moved within a field of stars.



Can you find the asteroid? Move your eyes back and forth quickly between the left and right images — a technique known as "blinking" — to find the point of light that has moved. Tim Puckett

Garradd, who quit his job as an accountant to devote full time to astronomy, spends many nights observing solo. But he is not alone. He belongs to a community of amateur astronomers from around the world who hunt evasive asteroids and other heavenly objects such as comets, variable stars, and supernovae — all in the name of science.

Numbering about 2,000, these vigilant astronomers work night after night at their modest backyard telescopes, gathering data useful for scientific research. Often, they work with middle-man organizations such as the Minor Planet Center, the American Association of Variable Star Observers (AAVSO), and the International Amateur-Professional Photoelectric Photometry (IAPPP), to name a few. These groups help amateur astronomers to select targets and then serve to organize the data for professionals. As a result, the amateur and professional seldom have the chance to meet face-to-face. But in some cases, the two work together, and the amateur gains a byline as a coauthor on a professional research paper.

But amateurs are not in it for the recognition. They're in it for the pleasure. "I don't want to spend the rest of my life behind a desk. I get enjoyment from doing something useful," says Garradd.

"Useful" is probably an understatement. In the field of astronomical research, data is the name of the game. Professional astronomers need large amounts of data in order to make accurate predictions, such as when a variable star might peak in brightness or whether an asteroid's orbit might cross Earth's. Scientists can rarely procure enough data themselves. Typically, they have limited access to large telescopes, where they must compete for observing time with hundreds of other astronomers. Even if an astronomer is granted observing time, he or she may receive only a couple nights per month — if that — to peer through the scope, and those nights might be ruined by clouds.

THE AMATEUR SKY SURVEY

When Comet Shoemaker-Levy 9 slammed into Jupiter's upper atmosphere back in July 1994, Tom Droege watched in awe. He also wondered how astronomers monitor the night skies for other potentially destructive interlopers. After asking around, he discovered that while some professionals were using a few huge telescopes to study areas of the sky, no one was looking at all of it. He envisioned a sky survey in which amateur astronomers would scan the heavens for renegade comets and asteroids and also the flickering of variable stars. Thus The Amateur Sky Survey (TASS) was born.

Today, about 150 amateurs participate in the project via the Internet. Here they learn which objects need study and are given a forum to present their data. To accumulate information, they use remotely operated CCD cameras mounted in "triplets" (see photo), which provide overlapping images offset by about 15°, or 30 times the width of a full moon. This allows the imager to capture a moving or flickering object in the field.

Presently the group is working on variable star measurements but expects to move on to comet and asteroid searches. New scopes currently under construction will be able to search for transient phenomena such as gamma-ray bursts and comets.

"In the past, one needed to attend a university to perform serious study," says Droege. "TASS demonstrates that it is possible to form a strong special-interest group using only communication over the Internet."

Astronomers can buy a camera unit for about $1,500. If you're interested in participating, please contact Droege at droege@wwa.com or check out the TASS website, www.tass-survey.org.

Photo by Tom Droege

"What happens the other 28 or 29 days of the month?" asks Steve Edberg, an astronomer at the California Institute of Technology's Jet Propulsion Laboratory in Pasadena, California, who has worked with amateurs in the past. "Certainly something is happening on a planet or a comet and you won't know unless you're watching it."

The answer, of course, is to have folks such as Garradd on the lookout. With him and the countless other amateurs around the world fixated on the night skies, the data bits become more numerous and the scientific results more secure.

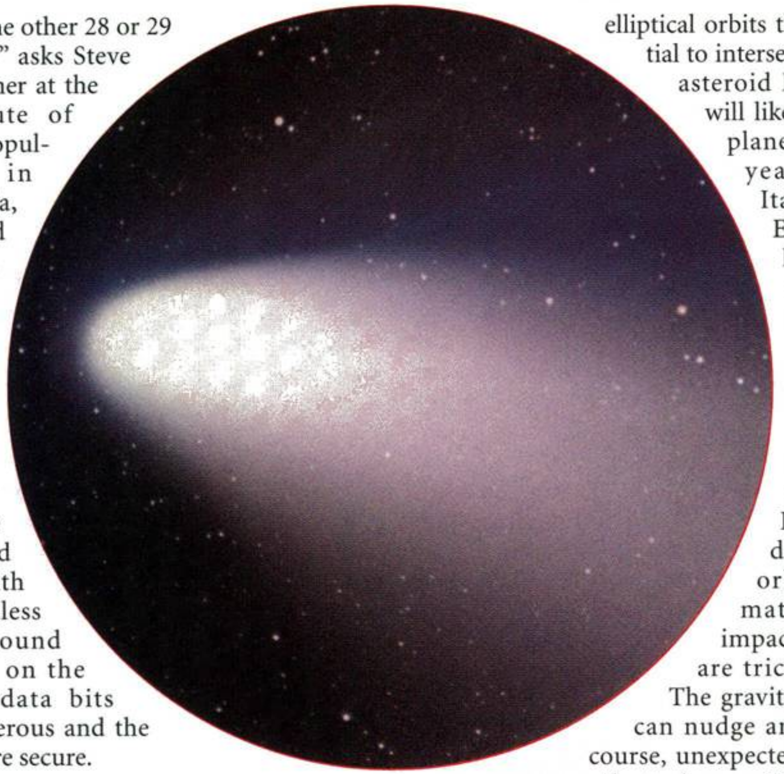
SAFEGUARDING EARTH

In this community of observers, fugitive asteroids remain some of the most tantalizing objects to pursue. They originate in the main belt, a band of asteroids orbiting the sun between Mars and Jupiter. When confined to this realm, they have no potential for impacting Earth and causing global disaster.

But a handful of other asteroids do. These belong to a broad category of cosmic debris known as Near-Earth Objects (NEOs). They revolve around the sun in elliptical orbits that have the potential to intersect Earth's orbit. The asteroid Eros, for example, will likely collide with our planet in a few million years, according to Italian astronomers. Eros is several times larger than the asteroid that wiped out the dinosaurs.

It's the potential for civilization-ending collisions that concerns professional astronomers most. If they can pin down an NEO's orbit, they can estimate when it might impact Earth. But NEOs are tricky critters to bag. The gravity of nearby planets can nudge an asteroid from its course, unexpectedly sending it on a new path. And many NEOs trace elliptical orbits, so they spend most of their orbits out beyond Mars, where they are exceedingly faint and difficult to detect. This means observers must keep tabs on an asteroid whenever possible.

"If you don't continue to observe these objects, you'll lose them," says asteroid tracker Richard



On January 30, 1996, Japanese amateur astronomer Yuji Hyakutake discovered a new comet using 25x150 binoculars. The comet was designated Comet C/1996 B2 (Hyakutake). John Chumack

OTHER WEBSITES OF INTEREST

Amateur Astronomers Kiosk	**sol.stsci.edu/~mutchler/HSTamateur.html**
American Association of Variable Star Observers	**www.aavso.org**
Association of Lunar and Planetary Observers	**www.lpl.arizona.edu/alpo/**
British Astronomical Association Comet Section	**www.ast.cam.ac.uk/~jds/**
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MarsWatch	**www.astroleague.org/marswatch/**
Minor Planet Center	**cfa-www.harvard.edu/iau/mpc.html**
Near-Earth Asteroid Tracking	**huey.jpl.nasa.gov/~spravdo/neat.html**
North American Meteor Network	**web.infoave.net/~meteorobs/**
Variable Star Network	**www.kusastro.kyoto-u.ac.jp/vsnet**

Kowalski, who works as a baggage handler for America West Airlines. "Then we'd have no idea whether an asteroid were coming at us or not."

But the handful of professional astronomers who search for NEOs are not enough to keep a watchful eye on these evasive objects, and as Minor Planet Center director Brian Marsden notes, "NASA funds only the search programs, not the follow-up."

Enter the amateur astronomer. Through a communication network hosted by the Minor Planet Center, an amateur can learn which asteroids need tracking. When an amateur such as Kowalski or Garradd nabs one, he reports its location and other characteristics to the Center, which maintains an index of detailed observations for the professionals. "We're tremendously impressed with what amateur astronomers are doing," says Marsden. "Our network wouldn't work without them. We are very grateful to the amateurs who do the follow-up."

BRIGHTER IS BETTER

"Amateurs are absolutely indispensable," says Janet Mattei, director of the AAVSO, an international organization that monitors the activity of another kind of celestial deviant: variable stars. These luminous balls of hot gas vary in brightness and sometimes in size.

Astronomers classify variable stars as intrinsic, where physical changes inside the star cause it to pulsate or erupt (such as a novae or supernovae), or extrinsic, where external forces such as starspots or a second star play a role. Mira, in the constellation Cetus, is a well-known example of a pulsating variable star. About every 11 months, it expands from a star that would fill our inner solar system to just beyond Earth's orbit to a star nearly the size of Mars's orbit — 150 times the diameter of our own sun. As it expands, it brightens from about magnitude 9 to magnitude 3, and then it shrinks and fades back to magnitude 9.

Amateur astronomers can measure a variable star's brightness most accurately using a simple device called a photometer. A photoelectric cell inside the photometer converts each incoming "particle" of light, or photon, into an electron. Electrons flowing through a wire make an electrical current. "You can measure the strength of the current. In so doing, you have measured the rate of incoming photons, which is the star's brightness," says Vanderbilt University astronomer Douglas Hall, who works closely with IAPPP, an organization dedicated to uniting professionals and amateurs for variable star research.

By monitoring the varying brightness of a star over time, known as a light curve, scientists can learn about the star's size, mass, temperature, luminosity, structure, composition, and age. This information can then be used to understand other stars. But again, a few professionals watching from a few spots on Earth a couple times a year just isn't adequate. Hundreds of observing eyes are needed. As Hall says, "Amateurs spread all over the world aren't going to be clouded out."

Through the AAVSO or IAPPP, amateurs can find out which stars need attention, because they might be currently observed with a satellite or large ground-based telescope. They can then submit their findings to the AAVSO International Database. To date, the database contains more than 9 million observations from AAVSO's founding in 1911 to the present. Or they can have IAPPP assist them in publishing their findings in a professional journal.

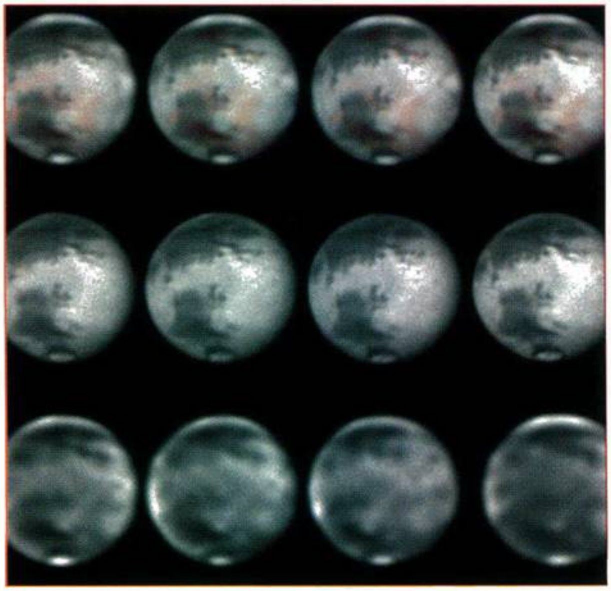
"If such a collaboration did not exist," says Mattei, "probably a lot of observing programs would not have been as successful." She cites the example of the European Space Agency Hipparcos satellite, which observed more than 6,000 variable stars during the 1990s. In order to make reliable and efficient observations, Hipparcos needed to know how bright some of the stars would be when it observed them. The AAVSO worked with a team of European professional astronomers in predicting the brightnesses of these stars using thousands of AAVSO observations. Every month, as new data came in to the AAVSO, the predictions were checked and revised if necessary and the scientists operating Hipparcos were alerted accordingly. "It became a very efficient way of observing these stars with the satellite," says Mattei.

MARSWATCH

These sorts of collaborations are not limited to the faint and far away. Don Parker, a retired anesthesiologist living in Coral Gables, Florida, uses his CCD cameras and two 16-inch scopes to conduct planetary science. In one night, he can easily snap off 400 raw images of Mars. To turn them into useable photographs, he must first process them with special software and then combine the images taken through red, blue, and green filters into one color composite.

Parker is renowned among professionals and amateurs alike for his mastery of this imaging technique. "He's definitely been the pioneer for solar system CCD imaging," says planetary scientist Jim Bell of Cornell University. "I would personally label him the premier amateur planetary observer."

Using a CCD camera and a 16-inch scope, Don Parker captured changing surface features on Mars, scientific data published in the March 1999 issue of the journal *Icarus*. Don Parker



Don Parker has patience only for the night sky, which he observes regularly from Coral Gables, Florida. Benny Millares/Wax Photographics

Bell met Parker in 1989 at a conference in Tucson, Arizona, and approached him to do some electronic imaging of Mars with special filters. Bell's goal was to obtain images of surface features and clouds — characteristics that provide clues to Mars's mineralogy and climate. The information gleaned could supplement data obtained from Mars Global Surveyor and the Hubble Space Telescope.

Between 1996 and 1997, Bell and Parker participated in a survey dubbed MarsWatch 97. Parker, along with more than 70 other amateur astronomers, uploaded electronic images to the MarsWatch website, which were then analyzed for mineral and climate characteristics. About 2,700 observations came in from all over the world, with the results of that work appearing in scientific papers in the March 1999 issue of the prestigious journal *Icarus*. Parker is the first author on one of those papers and is coauthor on another. This professional-amateur collaboration is continuing with the 1999 version of the MarsWatch website.

"If you look at the planets long enough," says Parker, who also serves as the executive director of the Association for Lunar and Planetary Observers, "you're probably going to discover something."

DIGITAL REVOLUTION

Amateur astronomers such as Garradd, Kowalski, and Parker represent a mere sliver of the community that participates in research. Despite their varied pursuits, two common things unite them: a love for astronomy and the availability of high technology.

"Any amateur with an 8-inch scope or larger with a reasonable clock drive and a CCD camera can do minor planet work," says amateur astronomer Mike Schwartz, a member of the Center for Backyard Astrophysics, another organization striving to unite amateurs and professionals.

Schwartz knows a little something about the technology making it easier for amateurs to get involved in science. He lives in Cottage Grove, Oregon, and operates his telescope in Arizona by remote. "In the evening, I connect to my telescope, give it its marching orders, and analyze the images the next day," he says. So far his strategy has netted him a dozen supernova discoveries.

CCD — or charge-coupled device — cameras work by employing a light-sensitive silicon chip originally developed for use in television cameras. When a CCD is struck by visible or ultraviolet light, it produces an electrical signal. The signal generates an image on a computer screen. CCDs are about 30 times more sensitive than standard photographic film and are therefore much better at capturing faint objects.

Star catalog software helps astronomers locate the object desired. Additional software helps convert, or reduce, the images into data that can be used by the middle-man organizations. As a result, an evening of observing becomes an evening in front of the computer. "I point and click to find stars, point and click to take a picture, and point and click to reduce the observations," says Schwartz.

Tim Puckett of Ellijay, Georgia, has taken the technology a step further. He has built a completely automated, robotic telescope to help find new asteroids and conduct supernova searches. Working with a computer programmer, he has developed software that shoots a mosaic of the sky, detects moving objects in the star field, pinpoints their position, and converts the data into a format that the Minor Planet Center can read. In one night he can shoot 250 galaxy fields, compared to the 50 or so possible with a manual scope.

"If you're moving a scope manually, forget it," says Puckett.

What's more, anyone with a sky catalog program and a CCD can call up his telescope on the Internet and control it remotely.

"I hear concern from professionals about quality because they just assume that amateurs are not qualified," says Columbia University astronomer Joe Patterson, coordinator of the Center for Backyard Astrophysics. "But it's clear their technical competence is very high."

It's no wonder. Amateurs use their own telescopes night after night and develop a high degree of familiarity with the process of taking data. And with the high ratio of amateurs to professionals, it only makes sense to tap into that talent. Professional astronomers who don't use amateur data are slowly becoming aware of the resource. The guidance of professionals paired with the enthusiasm of amateurs can only serve to advance the science of astronomy. Astronomers interested in pursuing research need only to reach out to one of the many organizations designed to bridge the gap between amateur and professional.

"If you do join, there's going to be a whole world of people willing to help you every step of the way," assures Schwartz. ■

Former Astronomy *associate editor Tracy Staedter is now managing editor at* Scientific American Explorations. *She is the author of* Rocks and Minerals, *a science book released this spring by Reader's Digest Children's Books.*

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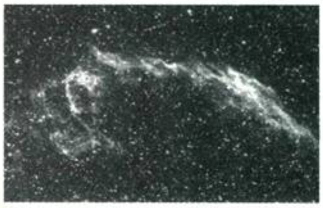

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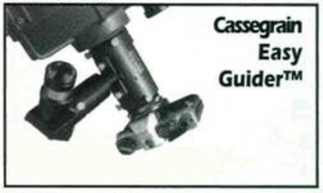

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Astronomy's

2000 Guide to the Sky

JAN

Under a Bloodred Moon

Two total lunar eclipses occur this year, and one is perfectly timed for observers in the United States. The first of the pair arrives on the night of January 20/21, when viewers across North America will be keeping their fingers crossed for clear skies. The second total eclipse takes place on July 16 and can be seen from Hawaii, Japan, Australia, and New Zealand. Only the early, partial stages of this eclipse will be glimpsed from the western mainland of the United States.

By its nature, a total eclipse of the moon can be seen from anywhere on the night side of Earth. That means people on slightly more than half our planet's surface can view at least some of the event.This is unlike a total solar eclipse, whose limited path streaks a pencil-thin line across Earth's sunlit hemisphere.

The winter full moon begins to slide into Earth's lighter, penumbral shadow shortly after 9 P.M. Eastern Time on January 20. About 30 minutes later, a noticeable darkening will become apparent on the lower left edge of the moon, which lies high in the eastern sky. At

Cover photo by Bruce Griffin

Keith Eisler

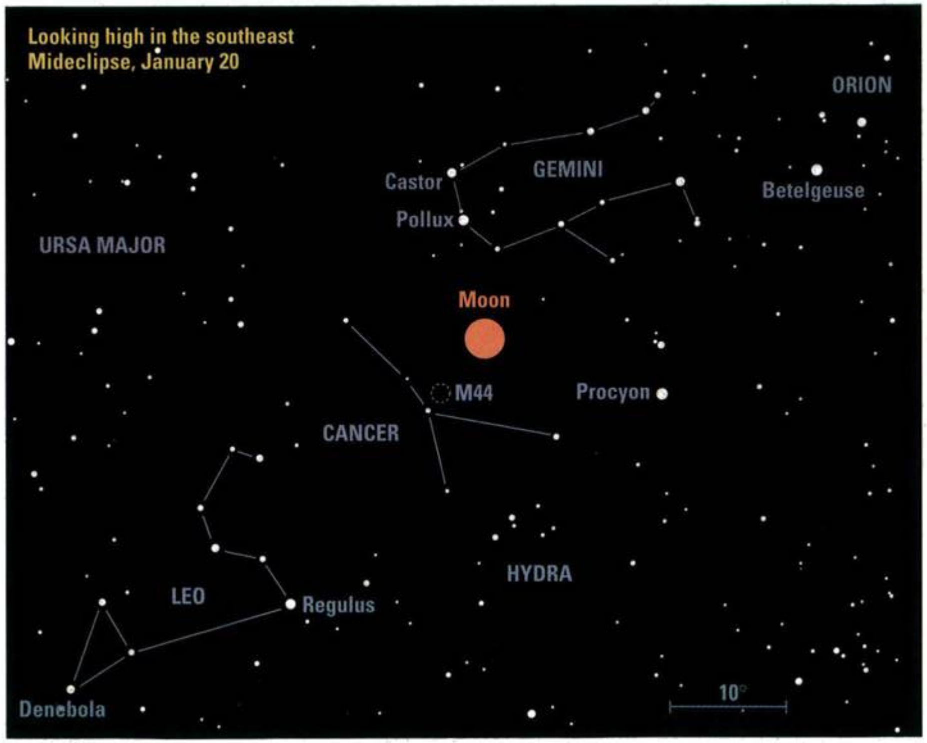
one minute past 10 P.M. EST, the moon reaches the edge of the darkest part of the shadow, called the umbra. For the next 63 minutes, the moon will edge deeper and deeper into Earth's shadow during the partial phase of the eclipse.

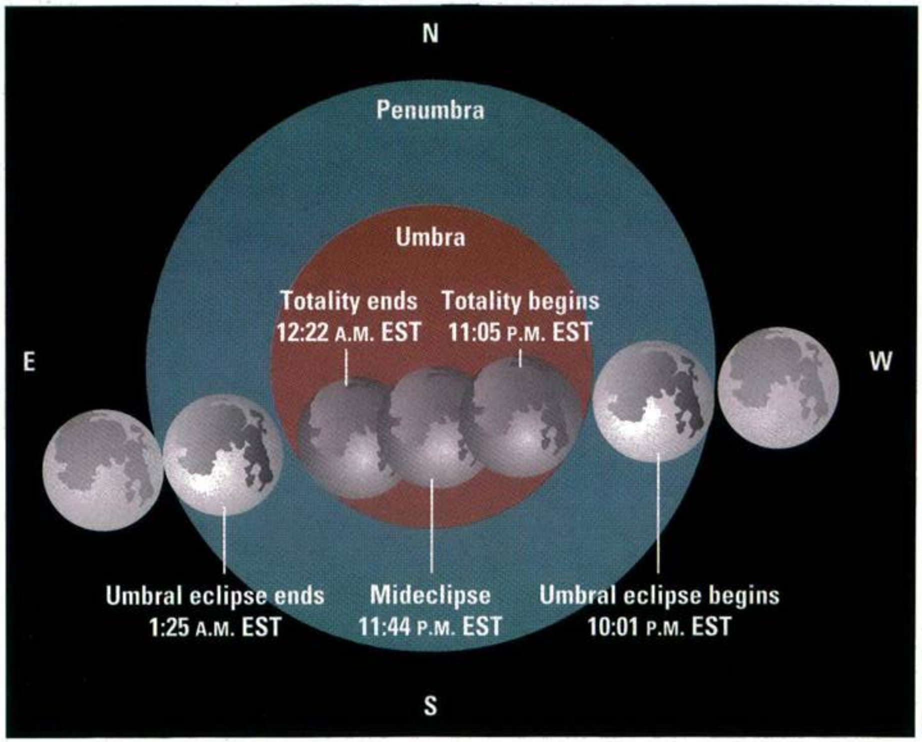
Initially the shadow will appear black in contrast to the rest of the moon, which remains in bright sunshine. As the partial phases progress, however, and more of the lunar surface becomes hidden in shadow, the moon starts to take on a dull orange hue. The color grows a brighter orange by the onset of totality. The transformation from the brilliant white full moon to the orange orb, hanging among the stars like a Christmas ornament, is spectacular.

Totality lasts for 78 minutes, during which time the brilliant stars of the winter sky will seem to shine ever more brightly as the glare of the moon gets attenuated. Jupiter and Saturn hang high in the western sky. Six degrees east of the moon, the fine open star cluster known as the Beehive (M44) also becomes easier to view. Seize this opportunity to look at the moon and M44 through binoculars — our shadowed satellite takes on a remarkable three-dimensional appearance set against the stars as opposed to the flat illumination of the full moon.

Totality ends at 12:22 A.M. EST, and during the following hour the moon slides back into full sunlight and each crater emerges from its brief respite from the sun's blistering radiation. Observers with an experimental inclination can watch the shadow pass over each lunar crater, timing its ingress and egress.

For North American observers, July's total lunar eclipse can be seen only from the western half of the continent, and then only the partial phases. Only those in the Hawaiian Islands will see totality begin before the moon sets. The partial phase of the eclipse begins at 4:57 P.M. Pacific Daylight Time.


Looking high in the southeast
Mideclipse, January 20
ORION
Castor
GEMINI
Betelgeuse
Pollux
URSA MAJOR
Moon
M44
Procyon
CANCER
HYDRA
LEO
Regulus
Denebola
10°


N
Penumbra
Umbra
Totality ends
12:22 A.M. EST
Totality begins
11:05 P.M. EST
E
W
Umbral eclipse ends
1:25 A.M. EST
Mideclipse
11:44 P.M. EST
Umbral eclipse begins
10:01 P.M. EST
S

All illustrations by *Astronomy*: Elisabeth Rowan

S	M	T	W	T	F	S
						1
2	3	4	5	○	7	8
9	10	11	12	13	◑	15
16	17	18	19	●	21	22
23/30	24/31	25	26	27	◐	29

EST

2 11 P.M.
The moon passes 3° north of Venus

4 Quadrantid meteor shower peaks

10 2 P.M.
The moon passes 1.9° south of Mars

15 noon
The moon passes 3° south of Saturn

8 P.M.
Mercury is in superior conjunction

17 3 P.M.
The moon passes 1.2° north of Aldebaran

20 midnight
Total lunar eclipse

24 1 P.M.
Neptune is in conjunction with the sun

26 10 P.M.
Pallas is at opposition

Events in **red** are ones you won't want to miss. All times in the calendar are eastern time. "Morning" or "evening" at the end of a listing denotes that the event appears before sunrise or after sunset, respectively.

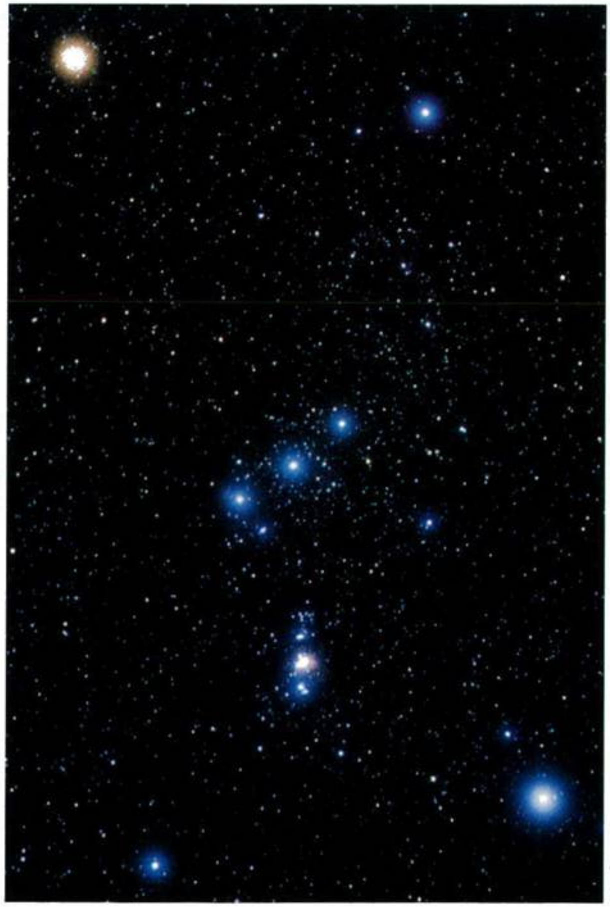
FEB

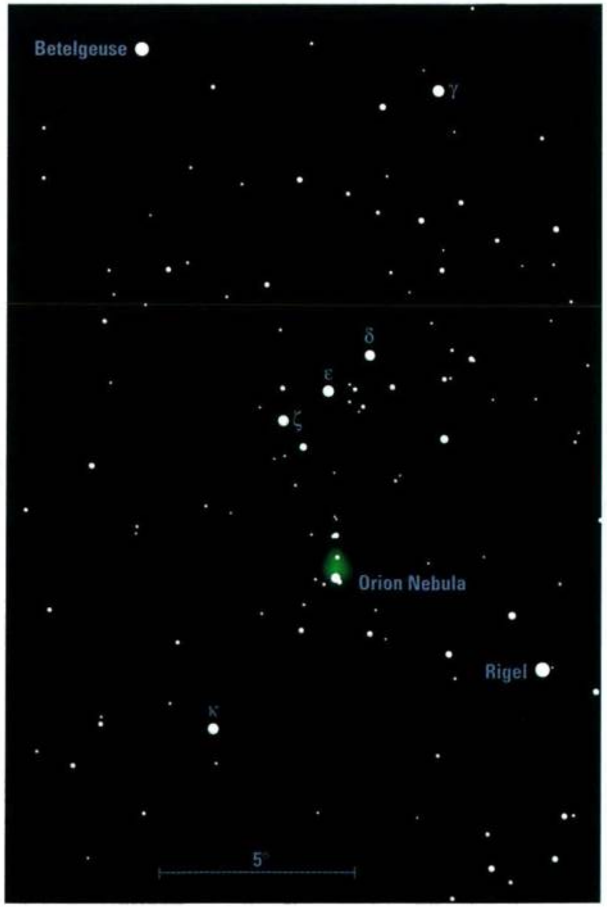
Target: Orion

Ask most any skygazer to list his or her favorite constellations, and Orion invariably will be near the top. The name instantly conjures up a multitude of images: a Greek hunter of mythic proportions, stars of astronomical size, and a spectacular nebula of delicate tendrils of gas and dust. The fact that Orion is so recognizable — the three bright, closely spaced stars in the constellation's midriff are unmistakable — draws many observers to this region first. February is the perfect time to view Orion because it lies high in the south after dusk.

Rigel, a star whose prodigious output ranks it among the brightest in the entire galaxy — it is 55,000 times brighter than the sun and possesses double the surface temperature — appears first in the darkening sky. Betelgeuse comes into view shortly afterward. Although cooler than our sun — it glows at a "mere" 3200 kelvins, which gives the star a bright red color compared with Rigel's bluish-white — Betelgeuse still shines 13,500 times brighter than our own star.

This power comes not from temperature but from sheer size. Betelgeuse is so large that even the term "red giant" seems hopelessly quaint; astronomers call Betelgeuse and its cousins red supergiants. With a diameter about 800 times that of the sun, this star would stretch well into the asteroid belt if it were to replace the sun at the center of the solar system. Knowing these facts as


John Chumack



you gaze at the brilliant speck of light with your naked eye, in binoculars, or with a telescope enables you to capture a sense of awe and wonder — and opens the mind to untold journeys.

The 20th century has revealed to us truly remarkable details in our quest to trace our origins. We have observed supernovae spreading heavy elements throughout interstellar space, seeding the surrounding gas clouds with enough material to form dozens of planets at a later epoch. The Hubble Space Telescope has photographed accretion disks of material around young stars. The story of every chemical element heavier than hydrogen and helium, the stuff that make up our planet and the rocky worlds around us, has been traced back to the nuclear cauldrons of bright, new, young stars.

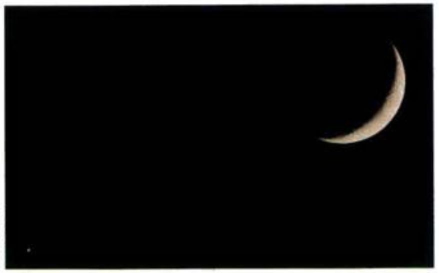
There, buried in the center of the Orion Nebula, are the four stars of the Trapezium — young stars beginning a new cycle. Their nuclear furnaces fuse hydrogen into helium. They illuminate the surrounding interstellar gas with ultraviolet light, making the hydrogen atoms glow pink and oxygen atoms glow green. These stars in the Orion Nebula are the newest generation in our galaxy.

On a dark night, you can spot the Orion Nebula below the belt stars of Orion with the naked eye, and binoculars will reveal the middle star of Orion's sword as plainly fuzzy. A low-power telescope will show the wispy gas cloud in its true splendor. As you gaze upon this nebula, ponder for a moment that you are witnessing a replay of your own atomic origins. Few things touch the human spirit deeper than that.

Winter's Dazzling Duo

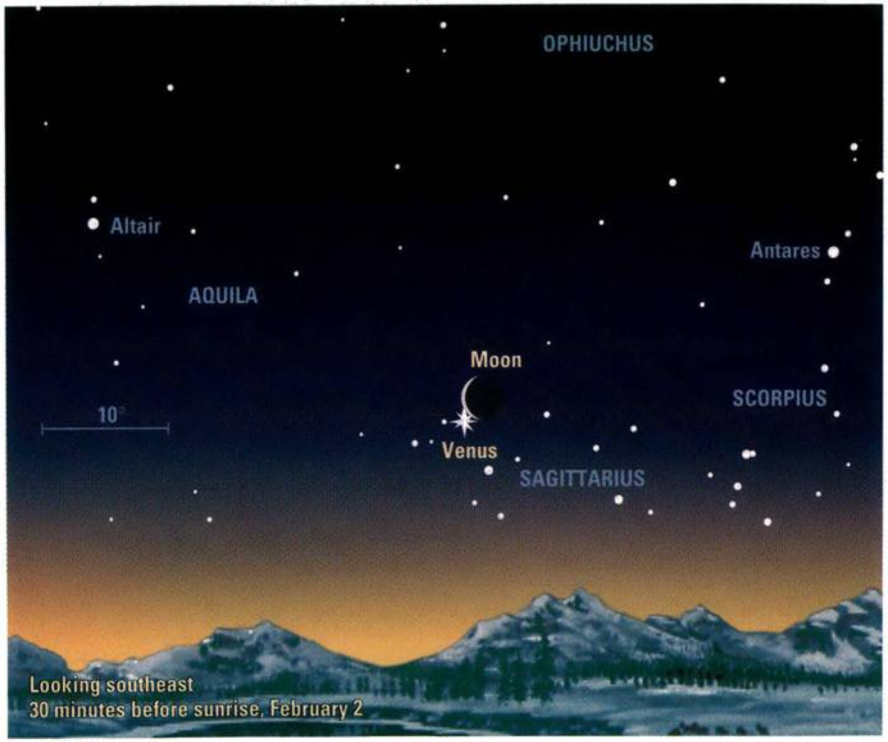
Few events inspire backyard skywatchers more than seeing a slim crescent moon standing next to a bright, starlike object. Whether you're looking at the night sky for the first time or you're a seasoned observer, the sight is sure to impress. This month offers one of the best such sights of the year, as the waning crescent moon passes less than 2° from brilliant Venus on the morning of February 2.

You can get a preview of the sight on the morning of the 1st, when the moon lies about 10° to the upper right of Venus. If sky conditions are good, you should see a faint illumination on the unlit part of the moon. Known as earthshine, this light comes about because whenever the moon shows a crescent phase, the moon "sees" a nearly full Earth. Earth is far bigger and more reflective than the moon, so it lights up the moon pretty well.



Peter Ledlie

By the morning of the 2nd, the moon has descended to a point just above Venus. With Venus the brightest object in the night sky (besides the moon, of course), the celestial pair is enough to grab everyone's attention. The planet currently shines at magnitude −4.0, a full ten times brighter than Sirius, the brightest star in the sky. The best view of the conjunction comes between an hour and 30 minutes before the sun rises, before twilight grows too bright. It's a sight you certainly won't want to miss.



Looking southeast
30 minutes before sunrise, February 2

S	M	T	W	T	F	S
		1	2	3	4	○
6	7	8	9	10	11	◑
13	14	15	16	17	18	●
20	21	22	23	24	25	◐
27	28	29				

EST

2 **10 A.M.**
The moon passes 1.4° north of Venus

5 **8 A.M.**
Partial solar eclipse (visible in Antarctica)

6 **2 A.M.**
Uranus is in conjunction with the sun

4 **3 A.M.**
Vesta is at opposition

8 **noon**
The moon passes 4° south of Mars

10 **9 P.M.**
The moon passes 4° south of Jupiter

11 **7 P.M.**
The moon passes 3° south of Saturn

13 **10 P.M.**
The moon passes 1.2° north of Aldebaran

14 **8 P.M.**
Mercury is at greatest eastern elongation (18°, evening)

22 **1 A.M.**
Venus passes 0.5° north of Neptune (morning)

MAR

Binoculars Reveal the First Asteroid

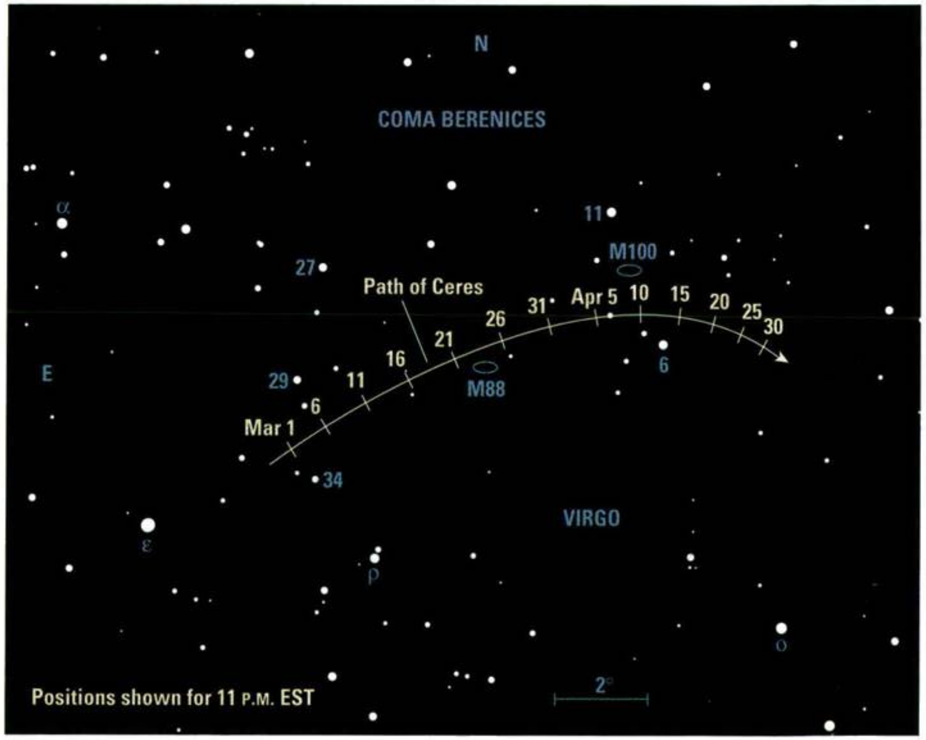
Ceres, easily largest of all the asteroids and the first to be discovered, comes to opposition this month. It then lies opposite the sun in our sky, rising at sunset and appearing high in the south around midnight. It also shines brightest at opposition: At magnitude 6.9, it lies well within the reach of binoculars and just beyond naked-eye visibility. Adding to the interest is the region of sky through which Ceres is wandering. During March, Ceres's westward track across the sky traverses the richest galaxy cluster in the sky, the Coma/Virgo group.

On February 10, Ceres began retrograde motion, its westerly path relative to the stars, when its normal eastward motion came to a halt just 2° west of the 3rd-magnitude star Vindemiatrix, or Eta (η) Virginis. Even then, Ceres was shining at magnitude 7.5, an easy binocular object. Now its path snakes across the border between Virgo and Coma Berenices on March 9. The asteroid officially reaches opposition on March 22.

A few nights before opposition, Ceres lies east of the bright barred spiral galaxy M91 (NGC 4548). During the night of March 20/21, watch Ceres as it traverses from one side of the 10th-magnitude galaxy to the other. The unwary watcher might suspect a bright supernova — since the presence of Ceres will change the appearance of the region when compared with photographs of the galaxy. Also, take care with the identification of M91. It is one of the "missing" Messier objects. In the past, it has been associated with NGC 4571, but more recently with the current identification, NGC 4548.

On March 25, Ceres passes a half degree north of M88 (NGC 4501). Because the region is relatively devoid of stars brighter than magnitude 7, Ceres should be easy to identify. The motion of Ceres relative to any star or galaxy in the same telescopic field of view should be evident within two to three hours — and a dead giveaway that the moving object is, indeed, the asteroid.

Ceres first came to light on January 1, 1801, when the Italian astronomer Guiseppe Piazzi discovered the 623-mile-wide object. The discovery came as a surprise to a group of six leading astronomers, led by Johann Schröter, who had teamed up to search for a suspected, much larger planet that was thought to lie between the orbits of Mars and Jupiter. After Piazzi's success, the "celestial police" continued the search and found Pallas in 1802, Juno in 1804, and Vesta, the brightest asteroid, in 1807.



Positions shown for 11 P.M. EST

Exploring the Spring Sky

The Big Dipper, our signpost in the sky, swings high overhead during the spring and lies near the center of our chart. This season of rejuvenation encourages us to move outdoors with the milder temperatures, and with it a new set of stars beckons us.

Follow the arc of stars outlining the handle of the Dipper away from the bowl and you will land on brilliant Arcturus. This orangish star dominates the spring sky in the kite-shaped constellation Boötes. Well to the west of Boötes lies Leo the Lion. You can find its brightest star, Regulus, by using the pointers in the Dipper in reverse. Regulus lies at the base of a group of stars shaped like a backward question mark, which represents the head of the lion.

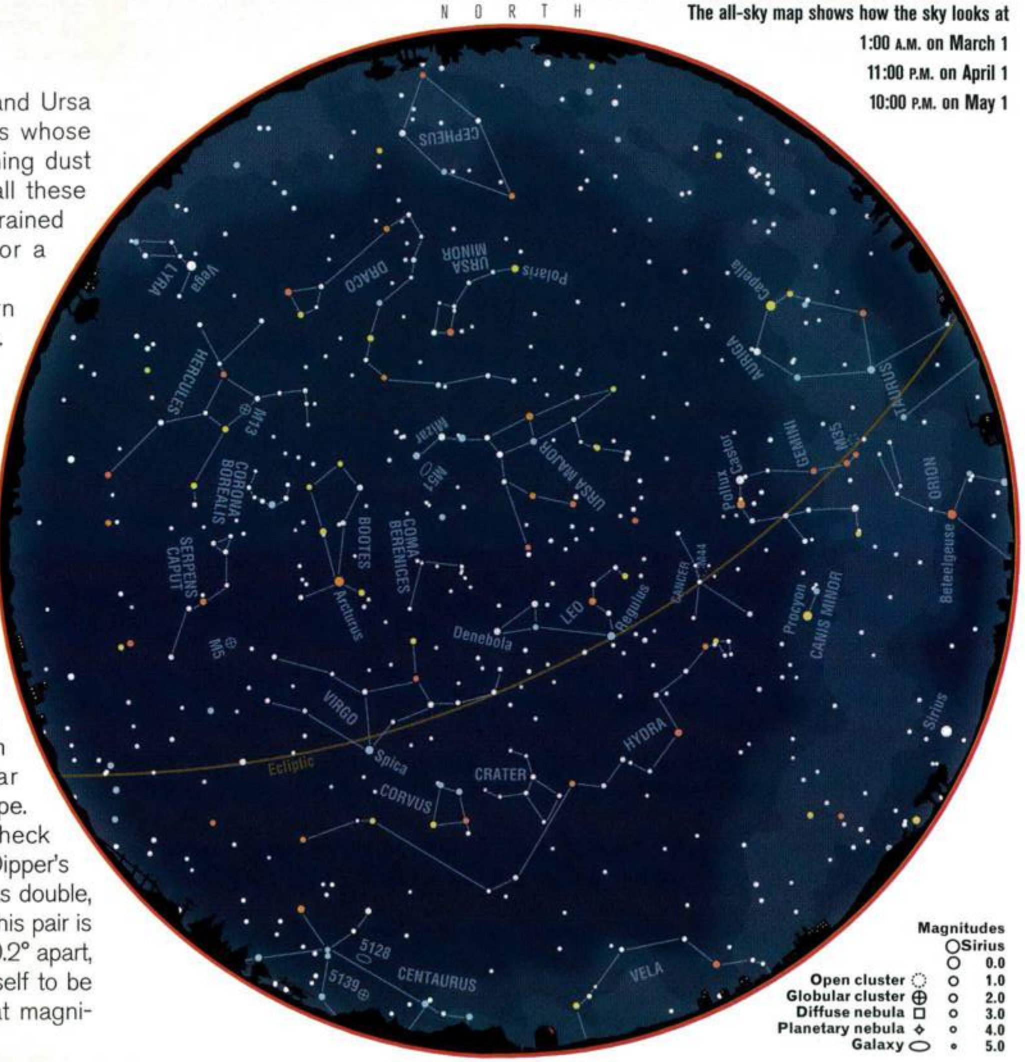
Midway between Regulus and Pollux in Gemini, which is now sinking in the west, is the diminutive group Cancer the Crab. Centered in the group is a hazy patch of light that binoculars reveal as the Beehive star cluster (M44).

To the southeast of Leo is the realm of the galaxies and the constellation Virgo the Maiden. Virgo's brightest star, Spica, shines at magnitude 1.0.

During springtime the Milky Way lies level with the horizon, and it's easy to realize that we are looking out of the plane of our galaxy. In the direction of Virgo, Leo, Coma Berenices, and Ursa Major lie hundreds of galaxies whose light is unhindered by intervening dust in our own galaxy. However, all these galaxies are elusive to an untrained eye and require binoculars or a telescope to be seen.

Boötes lies on the eastern border of this galaxy haven. Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, is a region where no star shines brighter than 2nd magnitude. A semicircle of stars represents Corona Borealis, and adjacent to it is a large region that houses Hercules, the fifth-biggest constellation in the sky. It's here we can find the northern sky's brightest globular cluster, M13. A naked-eye object from a dark site, it is spectacular when viewed through a telescope.

Returning to Ursa Major, check the second-to-last star in the Dipper's handle. Most people will see it as double, while binoculars show it easily. This pair is called Mizar and Alcor. They lie 0.2° apart, and a telescope shows Mizar itself to be double. Its companion shines at magnitude 4.0 and is 14" from Mizar.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M51
URSA MAJOR
Pollux
Castor
GEMINI
M35
TAURUS
ORION
Betelgeuse
SERPENS CAPUT
M5
BOOTES
Arcturus
COMA BERENICES
Denebola
LEO
Regulus
CANCER
M44
Procyon
CANIS MINOR
VIRGO
Ecliptic
Spica
CORVUS
CRATER
HYDRA
Sirius
5128
5139
CENTAURUS
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
1:00 A.M. on March 1
11:00 P.M. on April 1
10:00 P.M. on May 1

S	M	T	W	T	F	S
			1	2	3	4
5	○	7	8	9	10	11
12	◑	14	15	16	17	18
●	20	21	22	23	24	25
26	◐	28	29	30	31	

EST

1 **10 A.M.**
Mercury is in inferior conjunction

3 **7 P.M.**
Venus passes 0.07° south of Uranus (morning)

8 P.M.
The moon passes 0.6° south of Venus

8 **9 A.M.**
The moon passes 5° south of Mars

9 **noon**
The moon passes 4° south of Jupiter

10 **4 A.M.**
The moon passes 3° south of Saturn

14 **7 P.M.**
Mercury passes 2° north of Venus (morning)

20 **3 A.M.**
Equinox (northern spring/southern autumn begins)

22 **4 A.M.**
Ceres is at opposition

28 **4 P.M.**
Mercury is at greatest western elongation (28°, morning)

APR

A Grand Evening Conjunction

A spectacular retinue of planets congregates in the evening sky during April: On the 11th, Mars, Jupiter, and Saturn all lie within a 5° circle. The pair of giant planets, Jupiter and Saturn, began the year a modest 14° apart. By February both planets resided in Aries, where the rest of the evening action takes place during the spring. By April 1 the apparent distance between Jupiter and Saturn shrinks to 6° while Mars moves to within 2° of Jupiter. Of the trio, Jupiter is easily the brightest at magnitude –2.0, Saturn comes in at a still very bright magnitude 0.3, while Mars is some four times (1.5 magnitudes) fainter than Saturn.

On the evening of April 6, Mars and Jupiter approach closest to one another, when only 1.1° separate the pair. A wide-angle eyepiece on a short focal length telescope will show the pair in the same field of view. Coincidentally, but greatly adding to the scene, is a 2-day-old moon 3° south of Saturn. The addition of the crescent moon creates a spectacular foursome in the evening sky that becomes obvious just 30 minutes after sunset.

Five days later the three planets form a perfect equilateral triangle, and then on April 16 Mars passes 2° north of Saturn. In addition to being the faintest of the three planets, Mars stands out for its distinctive ruddy hue, which contrasts nicely with the yellowish glow of both Jupiter and Saturn.

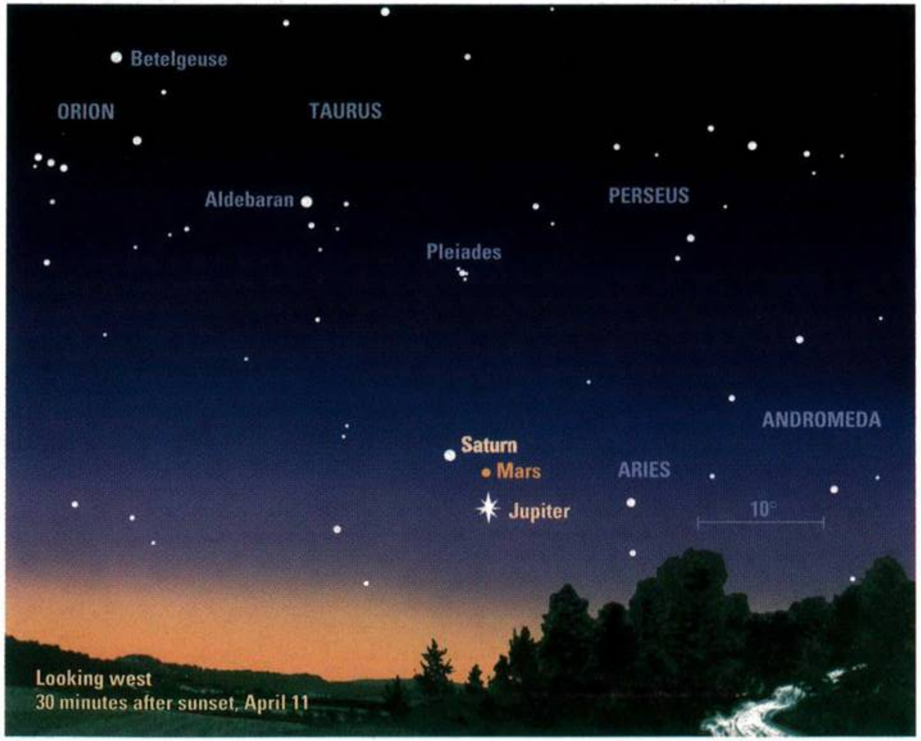
How frequently are these three planets together in the sky? Well, you may see them again at 20-year intervals, on March 26, 2020, and again on August 25, 2040, when Venus will join the trio. The last time the three planets were this close was on November 19, 1921.

As April closes, Jupiter and Saturn continue their fast slide into the sun's twilight zone, while Mars lingers rather longer. Jupiter reaches solar conjunction, when it lies on the far side of the sun from Earth, on May 8, and Saturn's takes place two days later. It will take another two months for Mars to reach solar conjunction because its speedier orbital motion helps it keep up better with Earth's motion around the sun.

Jim Anderson

PLANETARY CONJUNCTIONS IN 2000

Date	Planets	Time best seen
April 6	Mars and Jupiter	evening
April 16	Mars and Saturn	evening
April 28	Mercury and Venus	morning
May 31	Jupiter and Saturn	morning
August 10	Mercury and Mars	morning
December 11	Venus and Neptune	evening
December 23	Venus and Uranus	evening



Search for the Young Moon

Few things look as pretty as a slender crescent moon hanging low in the twilight sky. The ghostly crescent almost seems lost in the pinks, oranges, reds, and purples of twilight. This year, the first week of April provides the best opportunity to spot a very young moon.

Seeing the thin crescent depends on the time of year, the age of the moon, and observing conditions. Early spring is the best time because the ecliptic – the apparent path of the sun across the sky, which is also followed closely by the moon – makes a steep angle to the western horizon after sunset. That means the angular separation of the moon from the sun translates mostly into altitude above the horizon.

The moon's age measures the time since the previous new moon, the instant when our natural satellite passes between Earth and the sun. Seeing a one-day-old or younger moon requires a concerted effort. Fortunately, this month the moon will be slightly older and easier to spy.

New moon arrives at 2:12 P.M. on April 4, so by the time the sun goes down on the 5th, the moon is approximately 29 hours old. That makes it challenging to see, but not impossible.

Fabrizio Melandri

Begin your search about 20 minutes after the sun sets. Because the moon lies only a few degrees high, choose an observing location that provides a clear view right down to the western horizon. The weather must also cooperate. Any haze, smog, or clouds will likely have you pondering what might have been.

Scanning with binoculars just above the horizon offers your best hope, though once you do spot the crescent, try to see it with your naked eye too. And if you can't find it, don't despair: The glorious conjunction of the moon with Mars, Jupiter, and Saturn arrives just one day later, and that will provide a spectacular view.

S	M	T	W	T	F	S
						1
2	3	○	5	6	7	8
9	10	◑	12	13	14	15
16	17	●	19	20	21	22
23/30	24	25	◐	27	28	29

EDT

2 **8 A.M.**
The moon passes 1.6° south of Mercury

3 **2 A.M.**
The moon passes 3° south of Venus

6 **6 A.M.**
The moon passes 5° south of Mars
7 A.M.
The moon passes 4° south of Jupiter
5 P.M.
The moon passes 3° south of Saturn
7 P.M.
Mars passes 1.1° north of Jupiter (evening)

16 **7 P.M.**
Mars passes 2° north of Saturn (evening)

21 Lyrid meteor shower peaks

26 **2 P.M.**
The moon passes 1.0° south of Neptune

27 **6 P.M.**
The moon passes 1.3° south of Uranus

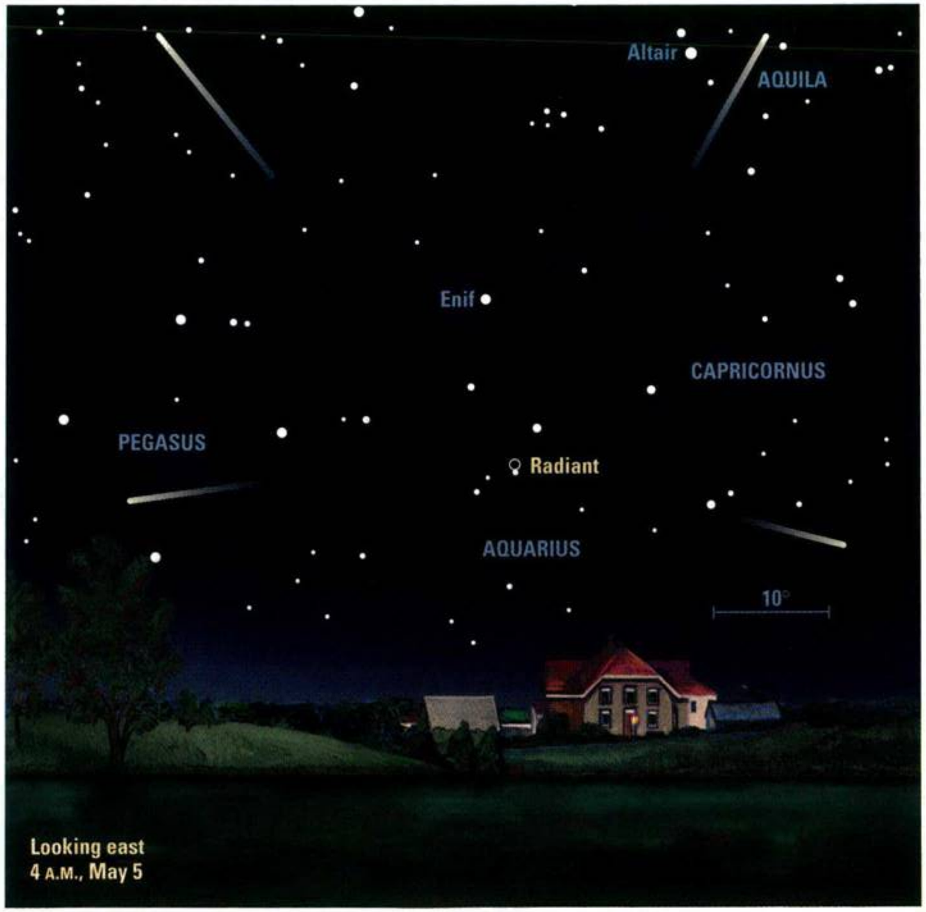
28 **5 A.M.**
Mercury passes 0.3° south of Venus (morning)

MAY

A Springtime Meteor Shower

Swift, bright meteors characterize the Eta (η) Aquarid meteor shower, which reaches its peak when the moon is out of the sky in the first week of May. The fast moving particles that create the Eta Aquarid meteors belong to one of the two annual showers related to Halley's Comet – they share a similar orbit to that venerable nomad. The other shower associated with Halley is the Orionids, which peak in October.

Last year moonlight interfered with viewing the Eta Aquarids, but this year conditions for the early morning shower are ideal. The lone complication in observing the shower comes about because the radiant rises only two hours before the onset of astronomical twilight. The radiant, the point in space from which the meteors appear to emanate, lies near the "Water Jar" asterism in the constellation Aquarius. This region remains low for most North American latitudes. Observers farther south get a better view over a longer period and, from the Southern Hemisphere, the Eta Aquarids rank as the top meteor shower of the year.



METEOR SHOWERS FOR 2000

Name	Peak date	Moon's phase	Prospects
Quadrantids	January 4	Full	Poor
Lyrids	April 22	First quarter	Good
Eta Aquarids	May 5	Waning gibbous	Poor
Perseids	August 12	New	Excellent
Orionids	October 22	Full	Poor
Leonids	November 17	Waxing gibbous	Good
Geminids	December 14	Waxing crescent	Good

The brilliance of these meteors generates the major interest — more than 40 percent leave persistent trains as they hit the atmosphere at speeds reaching 40 miles per second (65 km/sec). Although the peak of activity is predicted to occur on May 4, it pays to watch a few days either side of this date: In 1997 the peak occurred a day early. The peak is broad, giving almost a week of good activity above a zenithal hourly rate (the rate calculated for perfect observing conditions if the radiant were to lie directly overhead) of 30 meteors per hour. Smaller numbers of Eta Aquarids trickle in between about April 19 and May 28.

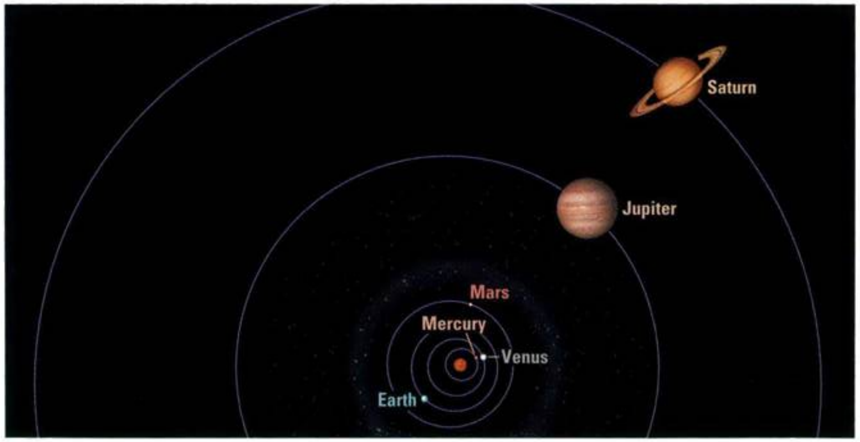
The flash of a meteor arises when a tiny particle of comet debris, typically no larger than a grain of sand, strikes our atmosphere at a colossal speed and instantly vaporizes. The visible, ionized trail is what we observe as a meteor. When a shower occurs, streams of material plow into the atmosphere. Each particle travels on a parallel track; observers on the ground get a perspective effect of the meteors apparently radiating from a single point in the sky when their trails are traced backward to an intersection point, the radiant.

A radio aerial tuned to a station some 200 miles away will pick up reflections off the ionized trails left in the atmosphere by meteors. The sudden and brief improvement in reception of a normally difficult-to-receive radio station indicates the passage of a meteor. The rates of radio meteors often run significantly higher than visual rates, and Eta Aquarids are a good shower to check this out. "Observing" meteor showers with a radio also has the significant advantage that observations can be carried out in daylight, and under cloud cover.

An Alignment for the Ages?

Much has been made, and will continue to be made, about this year's apparent alignment of Mercury, Venus, Mars, Jupiter, and Saturn. But it's much ado about nothing. Alignments of the planets occur often, and this year's apparent alignment is little different from dozens of events in the past. The closest alignment of the five planets occurs around May 5, though even then the planets are not in a straight line but spread over some 25°.

Unfortunately for observers, this year's planetary congregation occurs near where the sun lies in the sky, with most of the planets involved lying on the far side of the sun from Earth. This means that the so-called alignment is invisible from Earth. A view from above the solar system gives a true picture of the positions of the planets. Similar alignments have caused no ill effects to earthlings. However, even in this enlightened age, there are as many charlatans and soothsayers around the world as there have been in centuries past. The previous alignment of these planets occurred on February 6, 1962, and the next will come on September 7, 2040.



S	M	T	W	T	F	S
	1	2	3	○	5	6
7	8	9	◑	11	12	13
14	15	16	17	●	19	20
21	22	23	24	25	◐	27
28	29	30	31			

EDT

4 Eta Aquarid meteor shower peaks

5 2 A.M.
The moon passes 5° south of Mars

7 midnight
Jupiter is in conjunction with the sun

8 midnight
Mercury is in superior conjunction

10 4 P.M.
Saturn is in conjunction with the sun

18 11 P.M.
Mars passes 6° north of Aldebaran (morning)

19 7 A.M.
Mercury passes 7° north of Aldebaran (morning)
11 A.M.
Mercury passes 1.1° north of Mars (morning)

23 10 P.M.
The moon passes 1.2° south of Neptune

25 2 A.M.
The moon passes 1.5° south of Uranus

31 6 A.M.
Jupiter passes 1.2° north of Saturn (evening)
midnight
The moon passes 3° south of Saturn

Elusive Mercury at Its Best

Even at the best of times, Mercury's brief visits to the evening sky are not easy to see. Fortunately, this year the balmy evenings of June play host to the finest opportunity to view the elusive inner planet. Mercury never reaches any great angular distance from the sun, so when it is visible, it always lies in the twilight sky. This month's apparition is helped by the steep angle of the ecliptic — the apparent path of the sun across the sky that the planets also follow closely — to the western horizon at dusk. This places Mercury well above the horizon and extends its visibility after sunset.

WHEN TO SEE MERCURY IN 2000

EVENING

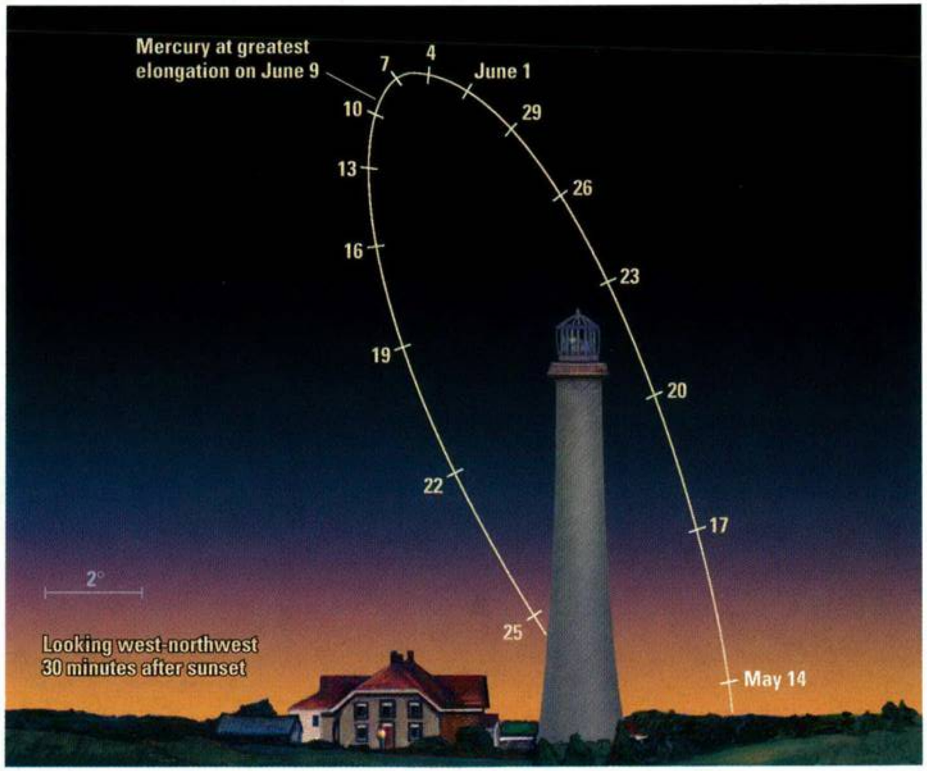
Greatest elongation	Visible from	Peak altitude
February 14	Jan. 29 to Feb. 24	11°
June 9	May 17 to June 27	13°
October 6	Sep. 1 to Oct. 24	3°

MORNING

Greatest elongation	Visible from	Peak altitude
March 28	Mar. 8 to May 1	5°
July 27	July 15 to Aug. 14	10°
November 15	Nov. 5 to Dec. 8	12°

Following its May 8 conjunction on the far side of the sun, Mercury scoots around its orbit, climbing quickly away from the setting sun in the evening sky. It skims past the 1.6-magnitude Mars, lying 1° northwest of the Red Planet on May 18 and already shining at magnitude –1.3. By early June, the tiny planet lies a healthy 21° east of the sun and sets almost two hours after the sun.

This apparition is a fine opportunity to watch Mercury's phase shrink in the eyepiece of a telescope. The planet appears 75 percent lit on May 24 and just half lit on June 4. The shrinkage in phase combines with a growth in the disk's apparent size — indicating that the distance between Earth and Mercury is rapidly decreasing. Between May 20 and June 20, Mercury grows from 5.5" across to a relatively respectable 10".


Mercury at greatest elongation on June 9
7
4
June 1
29
10
13
26
16
23
19
20
22
17
25
May 14
2°
Looking west-northwest 30 minutes after sunset

Greatest eastern elongation occurs on June 9, when Mercury lies 24° from the sun. Through a telescope, Mercury presents an ever-shrinking crescent. By June 23, Mercury sets just one hour after the sun and displays a crescent 17 percent illuminated. And by June 28, it can only be viewed in bright twilight.

Exploring the Summer Sky

The richness of the summer sky is exemplified by the splendor of the Milky Way. Stretching from the northern horizon in Perseus, through the cross-shaped constellation Cygnus overhead, and down to Sagittarius in the south, the Milky Way is packed with riches. These riches include star clusters, nebulae, double stars, and variable stars.

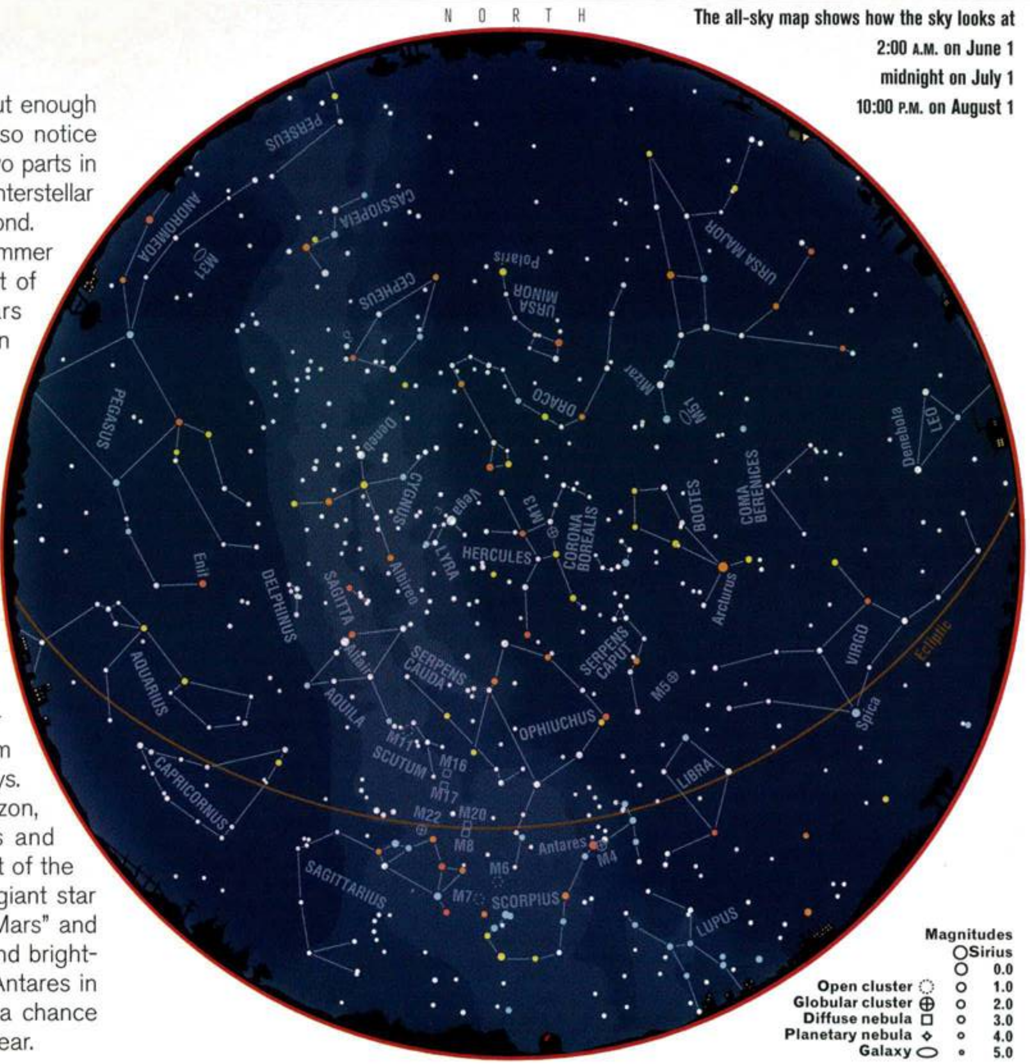
Let's start with the Big Dipper, our perennial stellar signpost, which now lies in the northwest with its handle still pointing toward Arcturus. High overhead and the first star to appear after sunset is Vega in Lyra the Harp. Vega forms one corner of the summer triangle, a familiar asterism of three stars. Near Vega is the famous double-double, Epsilon (ε) Lyrae. Two 5th-magnitude stars lie just over 3' apart and can be split in binoculars. Each of these two stars is also double, but you need a telescope to split them.

To the east of Vega lies the triangle's second star: Deneb in Cygnus the Swan (some see a cross in this pattern). Deneb marks the tail of this graceful bird, the cross represents its outstretched wings, and the base of the cross denotes its head, which is marked by the incomparable double star Albireo – a match of a 3rd-magnitude yellow star and a 5th-magnitude blue star offering the finest color contrast anywhere in the sky. Deneb is a supergiant star pumping out enough light to equal 60,000 suns. Also notice that the Milky Way splits into two parts in Cygnus, a giant rift caused by interstellar dust blocking starlight from beyond.

Altair, the third star of the summer triangle, is the second brightest of the three. Lying 17 light-years away, it's the brightest star in Aquila the Eagle.

Frequently overlooked to the north of Deneb lies the constellation Cepheus the King. Shaped rather like a bishop's hat, the southern corner of Cepheus is marked by a compact triangle of stars including Delta (δ) Cephei. This famous star is the prototype of the Cepheid variable stars used to determine the distances to some of the nearer galaxies. It varies regularly from magnitude 3.6 to 4.3 in 5.37 days.

Hugging the southern horizon, the constellations Sagittarius and Scorpius lie in the thickest part of the Milky Way. Antares is a supergiant star whose name means "rival of Mars" and derives from its similar color and brightness. Mars will pass north of Antares in September, providing us with a chance to see how similar the two appear.


NORTH
PERSEUS
ANDROMEDA
M31
CASSIOPEIA
CEPHEUS
Polaris
URSA MINOR
URSA MAJOR
Mizar
M51
DRACO
Deneb
CYGNUS
Vega
LYRA
M13
HERCULES
CORONA BOREALIS
BOOTES
COMA BERENICES
Denebola
LEO
PEGASUS
Enif
DELPHINUS
SAGITTA
Albireo
Altair
AQUILA
SERPENS CAUDA
SERPENS CAPUT
Arcturus
M5
OPHIUCHUS
VIRGO
Spica
Ecliptic
AQUARIUS
CAPRICORNUS
M11
SCUTUM
M16
M17
M22
M20
M8
Antares
M4
M6
M7
SCORPIUS
SAGITTARIUS
LIBRA
LUPUS
Magnitudes
Sirius
0.0
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5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on June 1
midnight on July 1
10:00 P.M. on August 1

S	M	T	W	T	F	S
				1	○	3
4	5	6	7	◑	9	10
11	12	13	14	15	●	17
18	19	20	21	22	23	◐
25	26	27	28	29	30	

EDT

1 **1 A.M.** The moon passes 4° south of Jupiter
2 P.M. Pluto is at opposition

3 **midnight** The moon passes 4° south of Mercury

9 **9 A.M.** Mercury is at greatest eastern elongation (24°, evening)

11 **7 A.M.** Venus is in superior conjunction

20 **3 A.M.** The moon passes 1.3° south of Neptune

10 P.M. Solstice (northern summer/southern winter begins)

21 **8 A.M.** The moon passes 1.6° south of Uranus

28 **4 P.M.** The moon passes 3° south of Saturn

9 P.M. The moon passes 4° south of Jupiter

JUL

Rogues of the Solar System

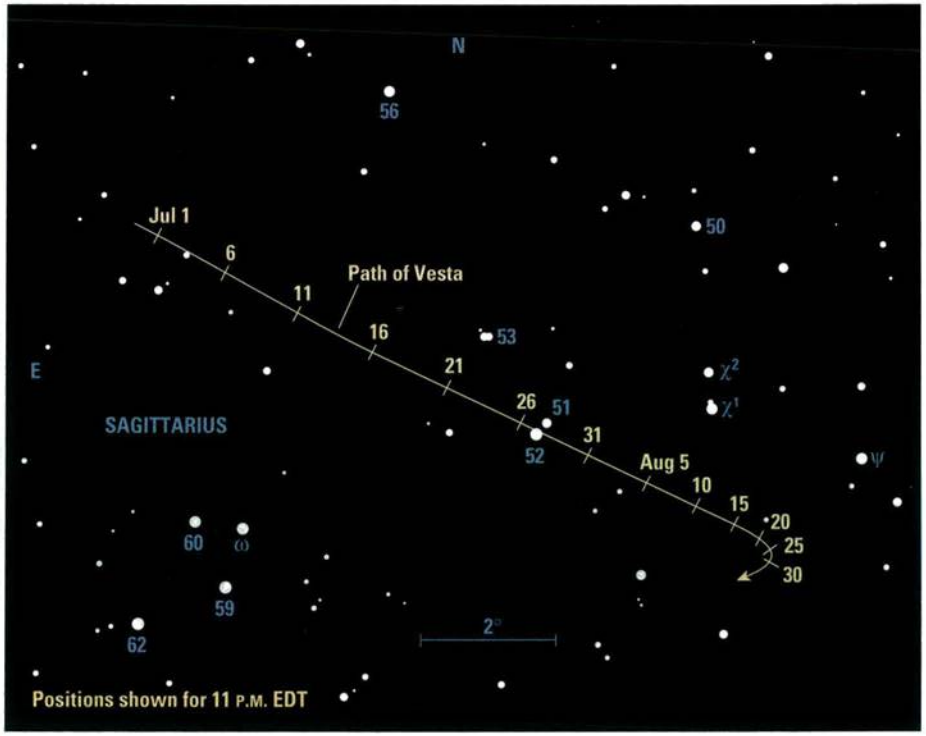
Flotsam...debris...leftovers from the formation of the solar system. Today, this material manifests itself in the form of comets and asteroids. Although two different names might seem to imply two different types of objects, growing evidence suggests a distinct overlap between comets and asteroids — a gray area where identifying something as a comet or asteroid is not so clear. What traditionally were called comets and asteroids are, perhaps, the two extremes of a continuous spectrum of material — low density objects in highly elliptical or parabolic orbits are comets while higher density, rocky objects in more circular orbits are asteroids.

This summer, a bright asteroid and a regular cometary visitor become relatively easy targets for the solar-system sleuth. Vesta was discovered nearly 200 years ago and was the fourth asteroid to be found. It comes to opposition on July 17. Comet Encke returns in its once-every-3.3-year sojourn to the inner solar system. It can be found in the predawn sky of late July and early August.

A mere 335 miles (540 km) across, Vesta nevertheless appears fairly bright because it reflects a high percentage of the sunlight striking it. In July it reaches a peak magnitude of 5.6, the brightest of any asteroid, as it wanders the rich starfields of Sagittarius.

On some days it will be easier to find than usual as it passes particular landmarks. For example, on midsummer's day (June 21), Vesta lies 1° north of M75 (NGC 6864), an 8.6-magnitude globular cluster on the border between Sagittarius and Capricornus. For Pacific rim observers who experience the spectacular total eclipse of the moon in mid-July (see below), Vesta lies less than 2° due south of the eclipsed moon, a fine opportunity to spot the interplanetary traveler.

Late in July, Vesta passes between 51 and 52 Sagittarii, a pair of stars that shines at magnitude 4.6 and 5.7, respectively. Vesta glows about as brightly as 52 Sgr, making that star appear double around July 28. Vesta's motion will be obvious if you observe the field then.



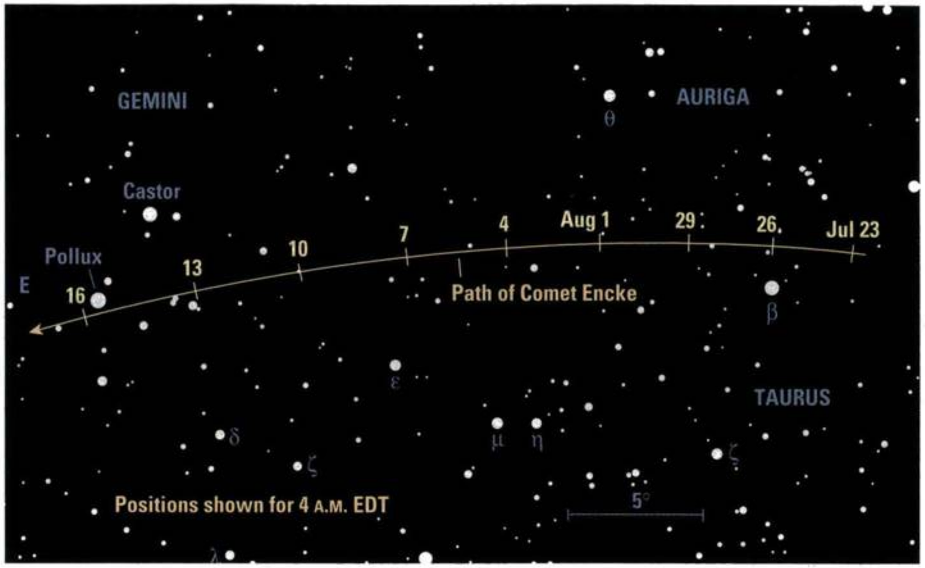
Positions shown for 11 P.M. EDT

Comet Encke makes a brief appearance in the predawn sky as it brightens toward perihelion, which occurs on September 9. Although it won't be one of Encke's best apparitions, it should be visible to those who make the effort. Check it out around mid-August, when it shines at 9th magnitude and passes less than a degree west of Pollux, the 1st-magnitude star in the constellation Gemini.

PERIODIC COMETS IN 2000

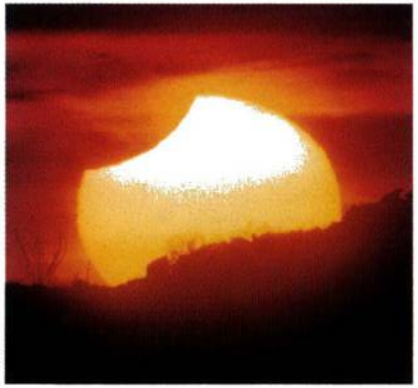
Name	Perihelion date
Tempel 1	January 2
Wiseman-Skiff	January 11
Ciffreo	April 18
Swift-Gehrels	April 21
West-Kohoutek-Ikemura	June 1
Daniel	June 23
Encke	September 9
Wolf	November 21

Yerkes Observatory



Positions shown for 4 A.M. EDT

A Trio of Eclipses



Ernest Piini

July brings with it a real rarity: Three eclipses to sink your teeth into. Unfortunately, no single locale will witness all three, but for those lucky enough to be in the right place at the right time, you'll have a great opportunity to bask in either the sun's or moon's shadow.

The activity gets started on July 1, when the moon passes partially in front of the sun for observers in southern South America and the South Pacific. At maximum eclipse, just under 50 percent of the sun's disk will be covered by the moon. If you happen to be in the favored region, remember to protect your eyes from the sun's blinding glare (see August for details on safe viewing).

The best of the three eclipses comes on July 16, when countries all around the Pacific Rim will have a front-row seat to a total lunar eclipse. The prime viewing areas are the Hawaiian Islands, eastern Asia, Australia, and New Zealand, though western North America will see the early stages. For those in North America and Hawaii, the eclipse gets under way on the morning of the 16th. (Across the International Date Line in eastern Asia, the eclipse begins on the evening of the 16th.)

This eclipse is special because the moon passes through the heart of Earth's shadow, barely missing the shadow's center. That means a long eclipse (totality lasts 107 minutes) with the moon appearing darker than usual.

The month's final eclipse is a partial one of the sun on July 30/31. Those in northern Asia and the western parts of the United States and Canada will see up to 60 percent of the sun blocked from view. From the Americas, the eclipse occurs just before sunset on the 30th, and the amount of the sun covered increases as you go farther north.

S	M	T	W	T	F	S
						○
2	3	4	5	6	7	◑
9	10	11	12	13	14	15
●	17	18	19	20	21	22
23/30	◐/31	25	26	27	28	29

EDT

1 **noon**
Mars is in conjunction with the sun
3 P.M.
Partial solar eclipse (visible in southern Chile and Argentina)

6 **8 A.M.**
Mercury is in inferior conjunction
4 P.M.
The moon passes 3° south of Jupiter

16 **10 A.M.**
Total lunar eclipse
2 P.M.
Vesta is at opposition

26 **5 A.M.**
The moon passes 2° south of Saturn

27 **5 A.M.**
Mercury is at greatest western elongation (20°, morning)
7 P.M.
Neptune is at opposition

29 **1 P.M.**
The moon passes 0.8° north of Mercury

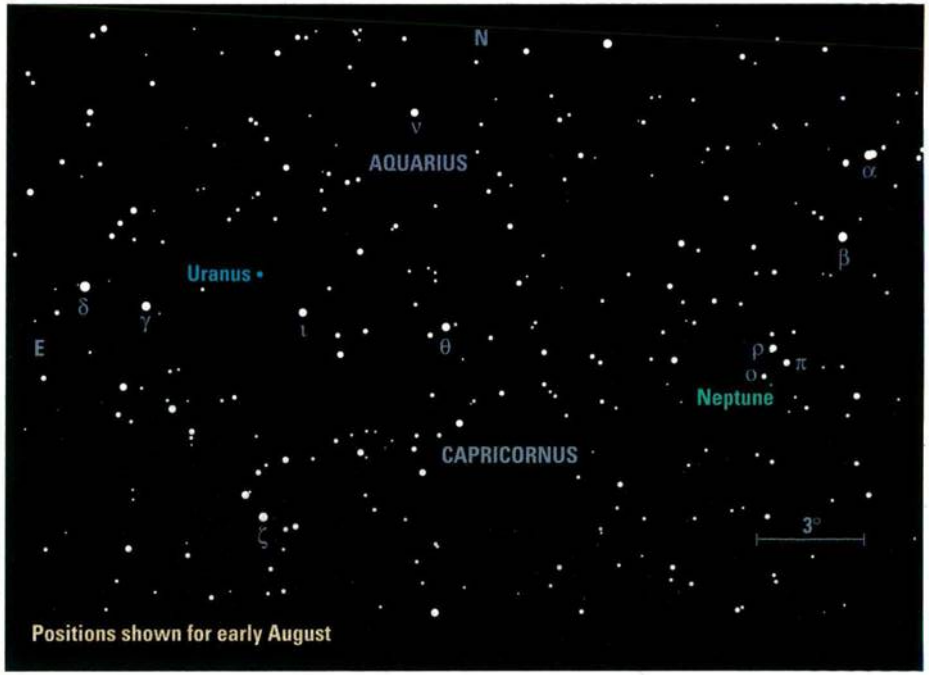
30 **10 P.M.**
Partial solar eclipse (visible in northern Europe and Asia and northwestern North America)

AUG

Land of the Distant Giants

Discovered in 1781 by Sir William Herschel, Uranus joined the known solar system 65 years before Neptune. Seven years ago, Uranus passed Neptune in the sky for the first time since they were discovered, and the two objects reached opposition on the same day. However, the relative proximity of Uranus causes it to move 4.3° per year compared with Neptune's more sedate 2.2° per year. Although the planets still reach opposition within a month of one another, Uranus has now crept almost 14° ahead of Neptune.

Of the two distant giant planets, Neptune comes to opposition first, on July 27. It will shine at magnitude 7.8 and lie near a trio of stars in western Capricornus: Pi (π), Rho (ρ), and Omicron (ο) Capricorni. For a few days on either side of opposition, Neptune lies in the same telescopic field as 6th-magnitude Omicron. This star is easy to find in binoculars or a telescope and provides a good guide for spotting the sun's eighth planet. Telescopically, Neptune appears as a dim, blue-gray disk a little over 2" across — far too small to notice any features.

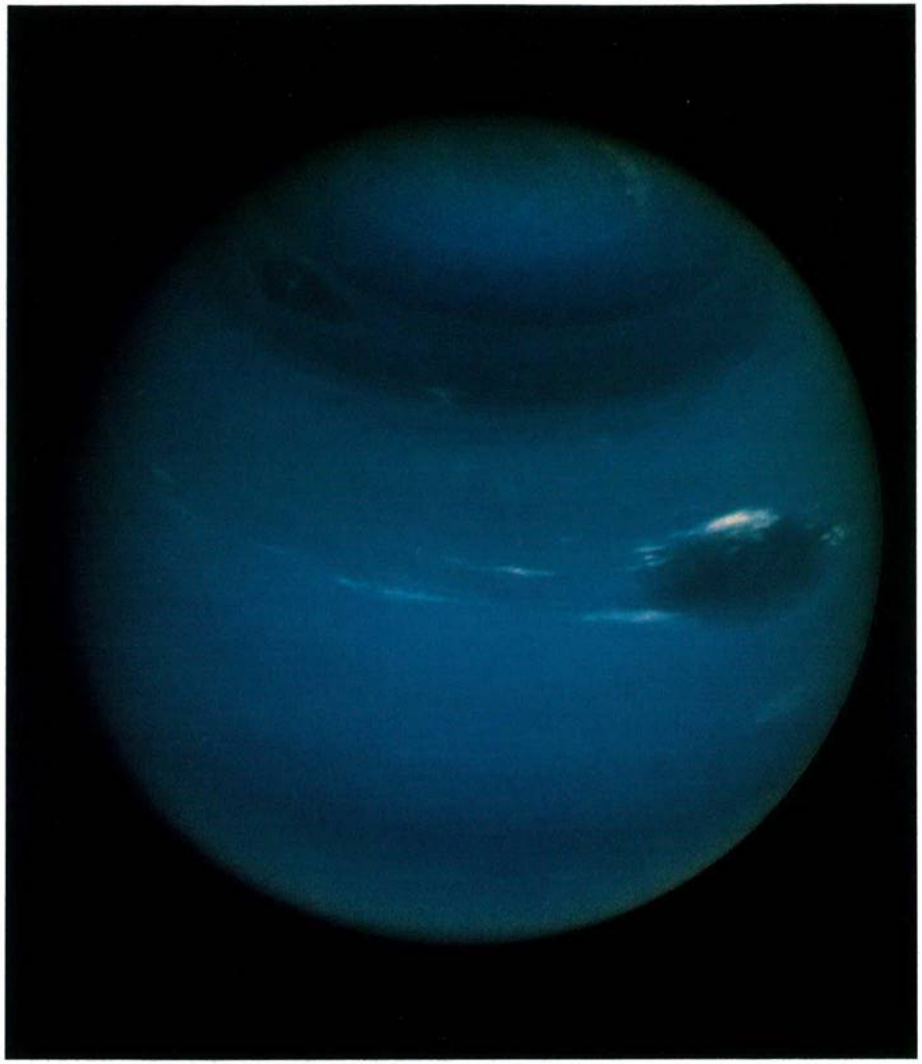


Positions shown for early August

Uranus reaches opposition on August 11. It then lies slightly more than 1° northeast of Iota (ι) Capricorni, a 4th-magnitude star found along the top of the broad, kite-shaped constellation. Uranus passes 40' north of this star on September 5.

Uranus shines at a respectable magnitude of 5.7 around opposition, making it visible to the alert naked eye under good dark-sky conditions. The 3.7"-diameter disk, like Neptune's, is too small to show any appreciable detail, but it appears distinctly greener than Neptune.

Another solar system object comes close to Uranus in the sky on July 15. On that day, the asteroid 4179 Toutatis passes about a degree to the northwest of Uranus. Toutatis is moving toward a near-Earth approach of just 7 million miles (11 million km) on October 31.


NASA/JPL

The Great Dark Spot dominates this Voyager view of Neptune, a far closer look than any earthbound scope can provide.

An Hour's Worth of Perseids

The peak of this year's Perseid meteor shower will find a bright moon in the sky for most of the night. Full moon arrives on August 15, just three days past the shower's August 12 peak. Although the gibbous moon certainly hinders meteor viewing, it sets about an hour before dawn encroaches on the dark skies of August 12, providing a brief window of excellent prospects. In fact, the hour before dawn is often the most active for a shower, with meteors striking our atmosphere at a higher relative velocity, resulting in brighter meteors. The Perseid shower is also strong enough that some meteors can be seen with the moon above the horizon, so don't give up even if you can't stay awake until the coming of dawn.

A Perseid meteor streaks past the Pleiades star cluster during one of the summer's annual observing rites.

John Volk

S	M	T	W	T	F	S
		1	2	3	4	5
◑	7	8	9	10	11	12
13	14	●	16	17	18	19
20	21	◐	23	24	25	26
27	28	○	30	31		

EDT

6 4 A.M.
Venus passes 1.1° north of Regulus (evening)

10 9 A.M.
Mercury passes 0.09° south of Mars (morning)

11 1 A.M.
Uranus is at opposition

12 4 A.M.
Juno is at opposition
Perseid meteor shower peaks

13 1 P.M.
The moon passes 1.1° south of Neptune

14 4 P.M.
The moon passes 1.4° south of Uranus

20 9 P.M.
Mercury is in superior conjunction

22 3 P.M.
The moon passes 2° south of Saturn

23 6 A.M.
The moon passes 3° south of Jupiter

27 11 P.M.
The moon passes 0.9° north of Mars

30 7 P.M.
The moon passes 4° north of Venus

SEP

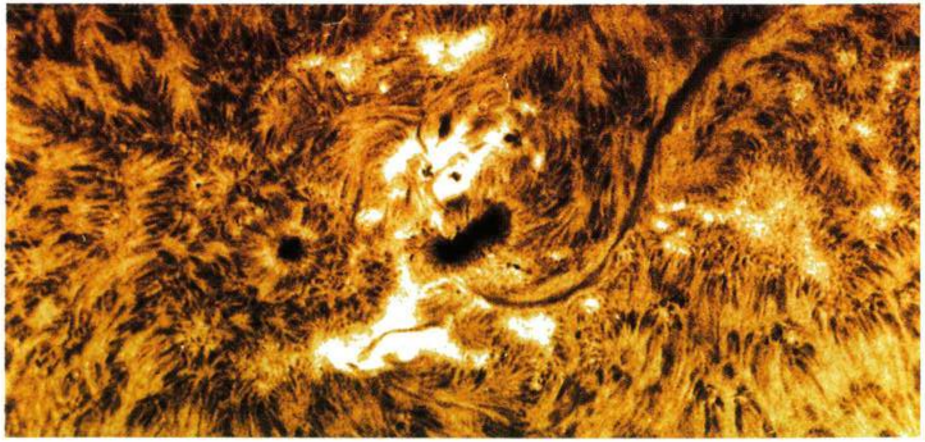
The Sun at Its Active Best

Solar max is here! Every eleven years or so, sunspot activity peaks and the sun's disk becomes pockmarked with dark blotches in larger numbers than usual. This year is the predicted peak, though the date can't be pinpointed until after the fact. Yet while astronomers can predict the approximate time of the peak, estimating the strength is more difficult.

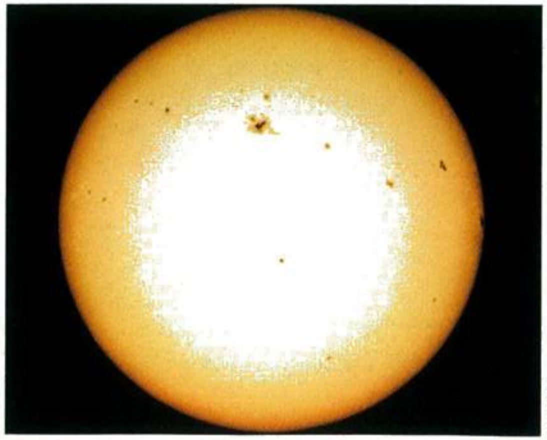
Astronomers think that sunspots are caused by a constriction in the solar magnetic field below the photosphere, the visible surface of the sun. This diverts the outflow of energy through a particular region and cools it. Although sunspots appear black against the solar surface, this is merely a relative effect — the photosphere shines at around 5800 kelvins while sunspots typically glow at 3800 kelvins and thus radiate far less light.

Tracking the progress of sunspots across the sun's face can make a nice observing project. You should find that a sunspot takes about 27 days to make one complete rotation around the equator. Because the sun is gaseous, however, it doesn't rotate as a solid body, and spots at higher latitudes take longer to make the same trip.

Sunspots also can change shape and size. Over a few days, a tiny dark pore can burst into a large, complex sunspot group — and its development is fascinating to watch. The safest way to view the sun is to project its image onto a white card or into a carefully built box attached to the eyepiece end of a telescope. This keeps your eye far from the intense light transmitted through any optical device. A magnifying glass directed at the sun can cause paper to smolder and catch fire. A telescope concentrates far more light and will do even more damage to your eye — so be careful.



Franz Kufer



Rick Dilsizian

ABOVE: A complex sunspot group seems to come alive when viewed in the light of hydrogen-alpha. This particular wavelength arises in the sun's chromosphere (a hotter layer lying immediately above the photosphere) and provides a better view of the active sun. For example, the bright white areas surrounding the sunspot group are called plages and represent higher temperature regions where the sun's magnetic field is stronger. **LEFT:** A more traditional, white-light photo of the active sun reveals plenty of sunspots. Solar maximum is defined as the time when the number of these spots reaches a peak – which obviously can't be determined until after the numbers start to fall off.

Exploring the Autumn Sky

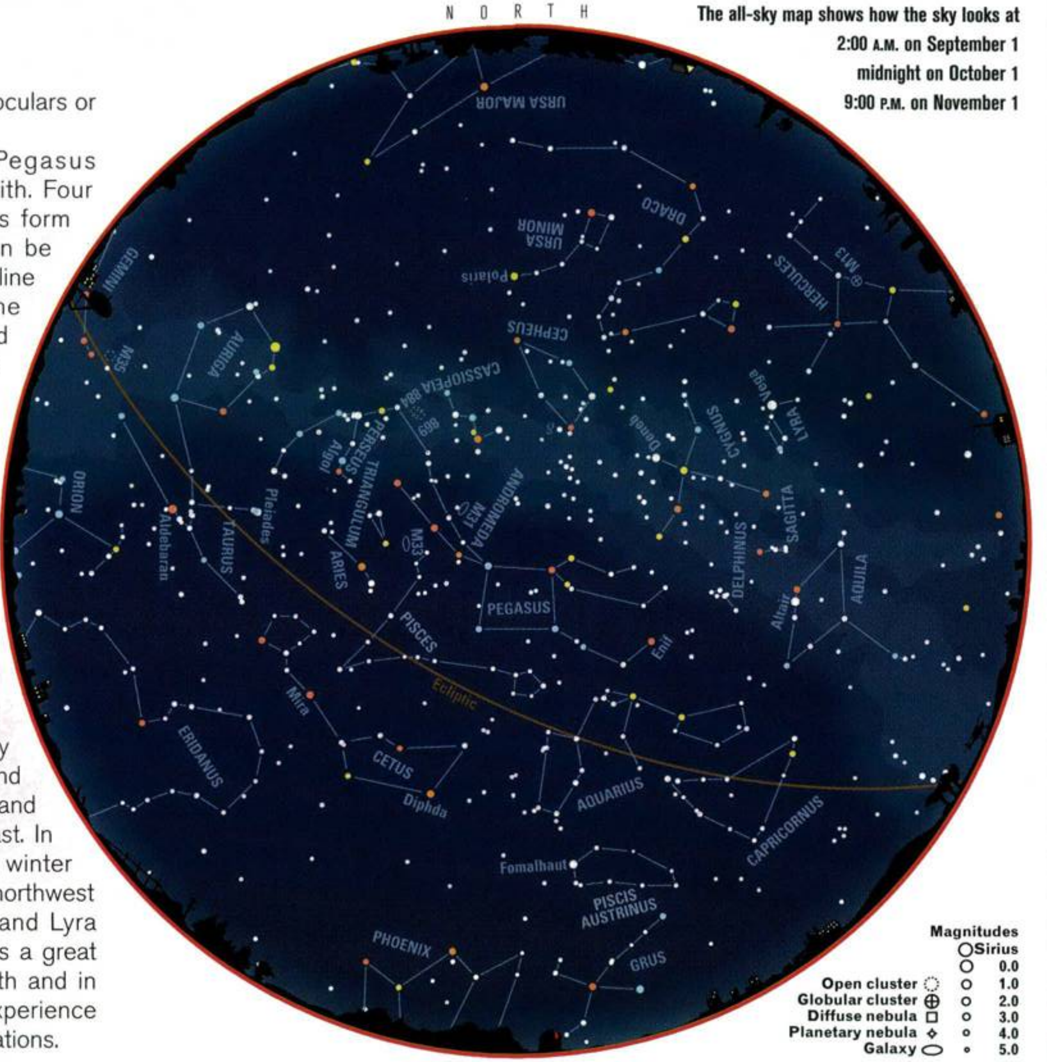
The cool nights of autumn are here to remind us that the chill of winter is not far off. Along with the cool air, the brilliant stars of the summer triangle descend in the west to be replaced with a rather bland looking region of sky. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to summertime, plus a couple of planets roam the region this year too.

The Big Dipper swings low this season, and for parts of the southern United States it actually sets. Cassiopeia, a group of five bright stars in the form of a "W" or "M," reaches its culmination overhead, the same point the Dipper reached six months ago. To the east of Cassiopeia, Perseus rises high. Nestled between these two groups is the wonderful Double Cluster – NGCs 869 and 884 – a fantastic sight in binoculars or a low-power telescope.

Our view to the south of the Milky Way is a window out of the disk of our galaxy in the opposite direction to that visible in spring. This allows us to look at the Local Group of galaxies. Due south of Cassiopeia is the Andromeda Galaxy (M31), a 4th-magnitude smudge of light that passes directly overhead between 9 P.M. and 10 P.M. in November. Farther south between Andromeda and Triangulum lies M33, a large, sprawling, face-on spiral best seen in binoculars or a rich-field scope.

The Great Square of Pegasus passes just south of the zenith. Four 2nd- and 3rd-magnitude stars form the square, but few stars can be seen inside of it. If you draw a line between the two stars on the right side of the square and extend it southward, you'll find 1st-magnitude Fomalhaut in Piscis Austrinus. Fomalhaut is the solitary bright star low in the south. Using the eastern side of the square as a pointer to the south brings you to Diphda in the large, faint constellation Cetus.

To the east of the Square lies the Pleiades Cluster (M45), which reminds us of the forthcoming winter. By late evening in October and early evening in December, Taurus and Orion are clear of the horizon and Gemini is rising in the northeast. In concert with the reappearing winter constellations, the view to the northwest finds summertime's Cygnus and Lyra about to set. The fall season is a great transition period, both on Earth and in the sky, and a fine time to experience the subtleties of these constellations.



NORTH
URSA MAJOR
URSA MINOR
Polaris
DRACO
CEPHEUS
HERCULES
M13
LYRA
Vega
CYGNUS
Deneb
CASSIOPEIA
884
869
PERSEUS
Algol
ANDROMEDA
M31
M33
TRIANGULUM
ARIES
AURIGA
GEMINI
M35
Pleiades
TAURUS
Aldebaran
ORION
PEGASUS
PISCES
Ecliptic
Mira
CETUS
Diphda
ERIDANUS
Enif
DELPHINUS
SAGITTA
Altair
AQUILA
AQUARIUS
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
GRUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on September 1
midnight on October 1
9:00 P.M. on November 1

S	M	T	W	T	F	S
					1	2
3	4	◑	6	7	8	9
10	11	12	●	14	15	16
17	18	19	◐	21	22	23
24	25	26	○	28	29	30

EDT

7 **2 P.M.**
Jupiter passes 5° north of Aldebaran (morning)

16 **3 A.M.**
Mars passes 0.8° north of Regulus (morning)

18 **3 P.M.**
Venus passes 3° north of Spica (evening)
9 P.M.
The moon passes 1.8° south of Saturn

19 **3 P.M.**
The moon passes 2° south of Jupiter

22 **1 P.M.**
Equinox (northern autumn /southern spring begins)

23 **11 A.M.**
Mercury passes 0.7° north of Spica (evening)

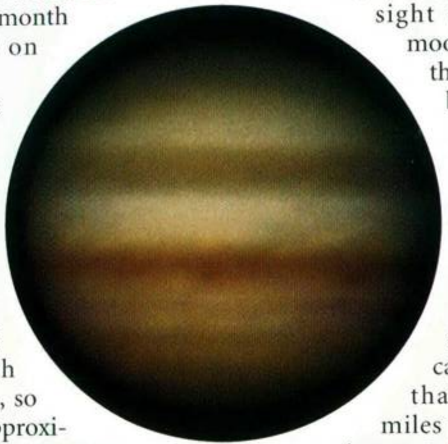
25 **1 P.M.**
The moon passes 2° north of Mars

29 **9 A.M.**
The moon passes 8° north of Mercury
8 P.M.
The moon passes 5° north of Venus

OCT

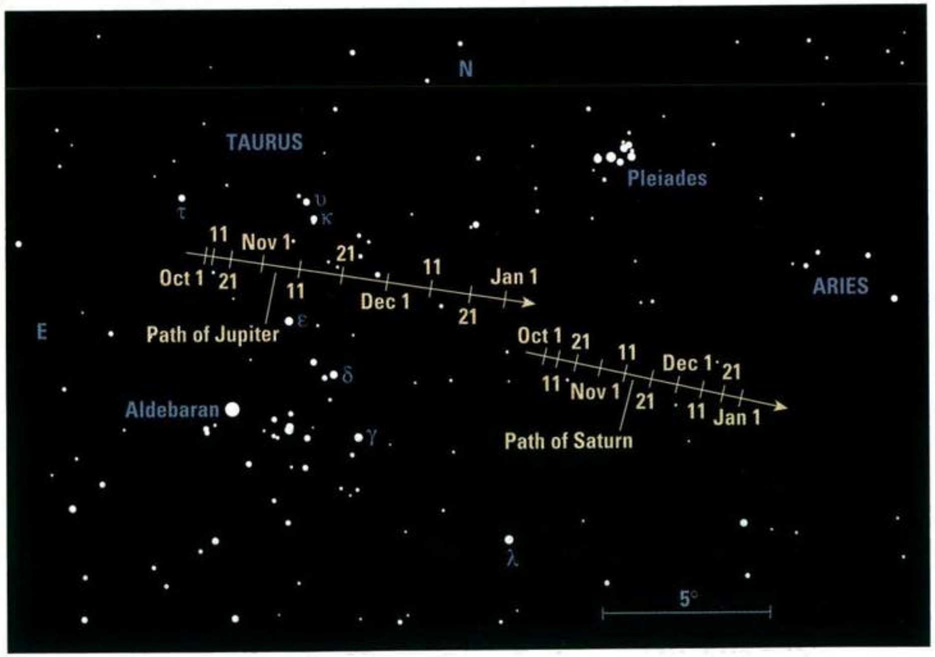
The King of the Planets at Its 12-year Peak

The constellation Taurus appears far different this year, with the dramatic arrival of the solar system's two largest planets. Jupiter and Saturn come to opposition within nine days of each other in November, so evening skygazers will really begin to notice the pair this month. Jupiter reaches opposition on November 28, when it lies 4 astronomical units from Earth, its closest approach to our planet since 1988. Saturn's opposition (see next month for details) occurs on November 19.

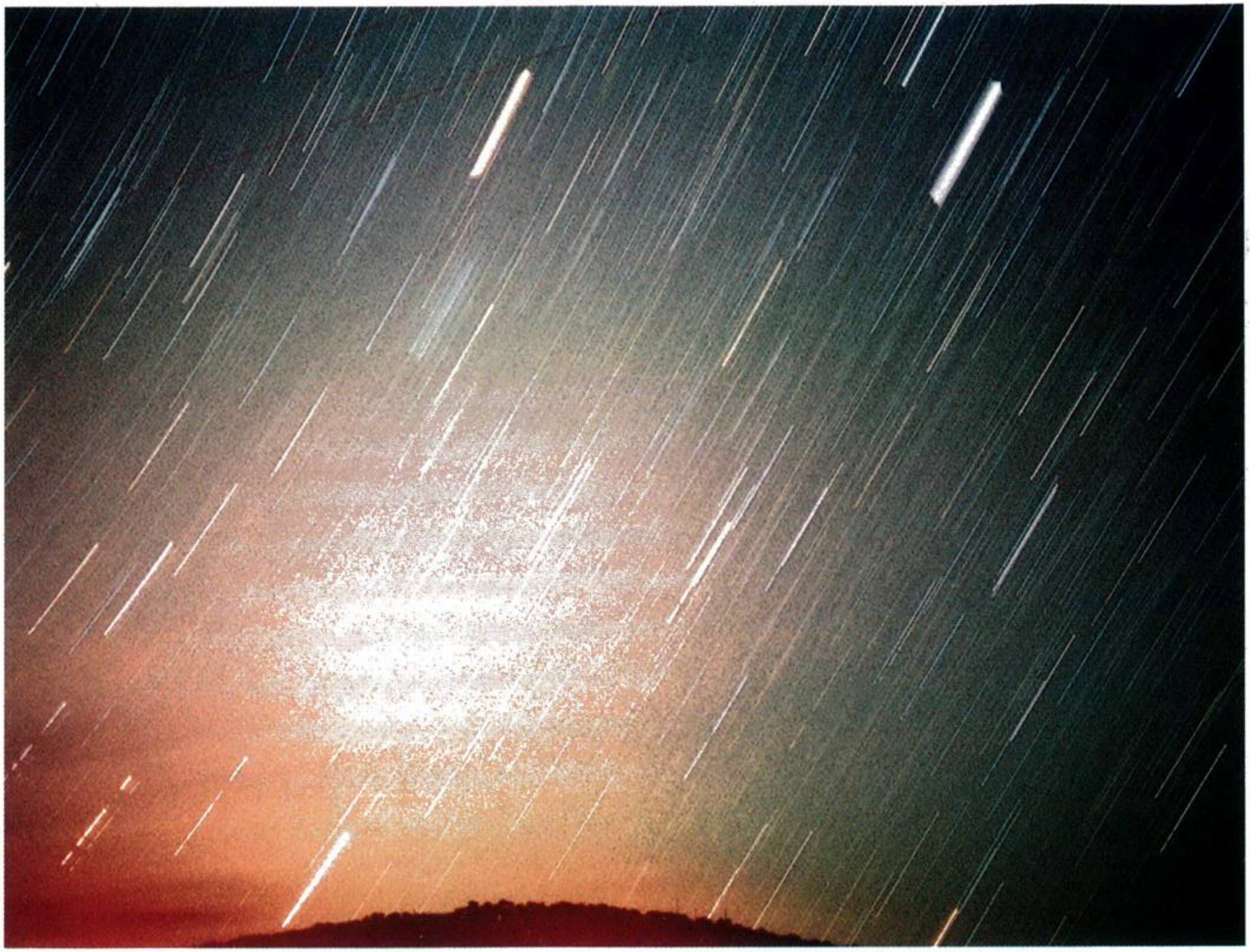

Leroi Teiva

Jupiter overtook Saturn shortly after the pair reached conjunction in May and has since pulled ahead of the Ringed Planet. Jupiter orbits the sun once every 11.86 years compared with 29.5 years for Saturn, so Jupiter laps Saturn approximately every 20 years. During the months leading up to opposition, both planets traverse the regions of Taurus near the Pleiades and Hyades star clusters. Jupiter passes 5° south of the Pleiades on June 24 with Saturn trailing the giant planet by 3°. On the morning of June 28, there was a beautiful sight when the crescent moon stood southwest of the planetary duo right before dawn.

Telescopically, Jupiter shows the finest atmospheric detail of any planet. Delicate wisps, spots, festoons, and belts lick the visible surface, all dramatically sculpted by winds that gust up to 1,000 miles per hour. For all its size — Jupiter is 12 times the diameter of Earth — it rotates in less than 10 hours. This breakneck speed distorts the gaseous globe from a perfect sphere into an oval — an effect you can see easily in any size telescope. The planet's equatorial diameter at opposition measures 48" while its polar diameter is some 3" less.



On November 28 Jupiter reaches its opposition magnitude of –2.9, outshining all objects in the sky except the sun, moon, and Venus. It dominates the winter evening skies for the rest of the year, drawing attention to the attractive star clusters that surround it. Its westward, or retrograde, path causes it to loop above the beautiful stars of the Hyades, and the bright red eye of the bull, Aldebaran, watches carefully. Don't miss Jupiter this year, its dramatic appearance will not disappoint you.



Astronomy: John Shibley

Dawn's Faint Glow

While Jupiter and Saturn blaze throughout these long autumn nights, a much subtler light beckons early morning observers. An hour or two before the start of morning twilight, look toward the east for a huge, softly glowing pyramid of white light. Known as the zodiacal light, or "false dawn," this ethereal glow is guaranteed to impress any skywatcher.

As its name implies, the zodiacal light hugs the zodiac, the broad band of sky that contains the paths of the planets. From mid-northern latitudes, the light is easiest to see on mornings in September and October and evenings in February and March. That's when the zodiac makes a steep angle to the horizon.

But the subtlety of the zodiacal light means you need the right conditions to see it. Observe from a dark site on a crystal-clear morning when the moon is out of the sky (the first 10 days of October are ideal). And use your naked eye – any optical aid renders the light invisible. At its brightest, it is a little brighter than the Milky Way.

The zodiacal light is actually sunlight reflecting off dust particles in the plane of the solar system. Most of the dust comes from spent comets or the debris created when asteroids collide.

S	M	T	W	T	F	S
1	2	3	4	◑	6	7
8	9	10	11	12	●	14
15	16	17	18	19	◐	21
22	23	24	25	26	○	28
29	30	31				

EDT

6 **6 A.M.**
Mercury is at greatest eastern elongation (26°, evening)

7 **2 A.M.**
The moon passes 1.3° south of Neptune

8 **4 A.M.**
The moon passes 1.5° south of Uranus

16 **2 A.M.**
The moon passes 1.6° south of Saturn
8 P.M.
The moon passes 2° south of Jupiter

21 **1 A.M.**
Jupiter passes 5° north of Aldebaran (morning)
Orionid meteor shower peaks

24 **1 A.M.**
The moon passes 3° north of Mars

26 **6 P.M.**
Venus passes 3° north of Antares (evening)

29 **9 P.M.**
Mercury is in inferior conjunction

30 **3 A.M.**
The moon passes 4° north of Venus

NOV

Ring Around the Ringed Planet

Joining the brilliant planet Jupiter in Taurus this year is the magnificent ringed planet, Saturn. It reaches opposition just south of the Pleiades star cluster on November 19, when it lies 8.4 astronomical units from Earth. Saturn is heading toward perihelion, or closest distance to the sun, which it will reach in 2003. That places it slightly closer to Earth this year than on average. In addition, the rings are now tipped more open to our line of sight than they have been in nine years. These effects combine to make Saturn brighter than it has been in a decade. Although still two magnitudes fainter than Jupiter, Saturn shines at magnitude –0.4 at opposition. The planet's true appeal outshines anything Jupiter can throw at her — the rings.

Anthony Obra

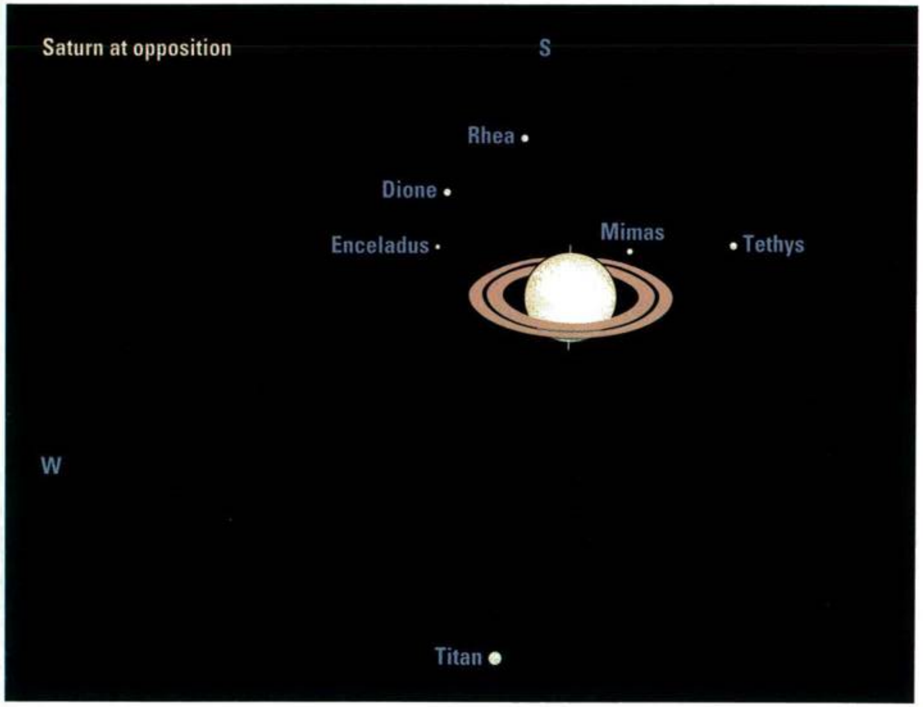
The vaunted rings, which can be seen in any telescope, capture everyone's imagination. The disk of Saturn measures just half that of Jupiter, about 20" across, but the rings make up for the difference with a long axis that spans 46".

This month Saturn lies 6° south of the Pleiades and 11° west of the Hyades. The full moon in November stands just 3° southwest of Saturn on November 12 and passes a similar distance south of Jupiter on the following evening. Both Jupiter and Saturn are moving along their retrograde routes, which takes them back along previously trodden paths south of the Pleiades. By year's end, Jupiter's larger retrograde loop brings it back within 7° of Saturn and 5° south of the Pleiades.

Details on Saturn's disk are always tricky to see because of the atmospheric haze, but bright white clouds occasionally appear. They whip around the planet in about 11 hours, giving Saturn the second fastest rotation rate of any planet.

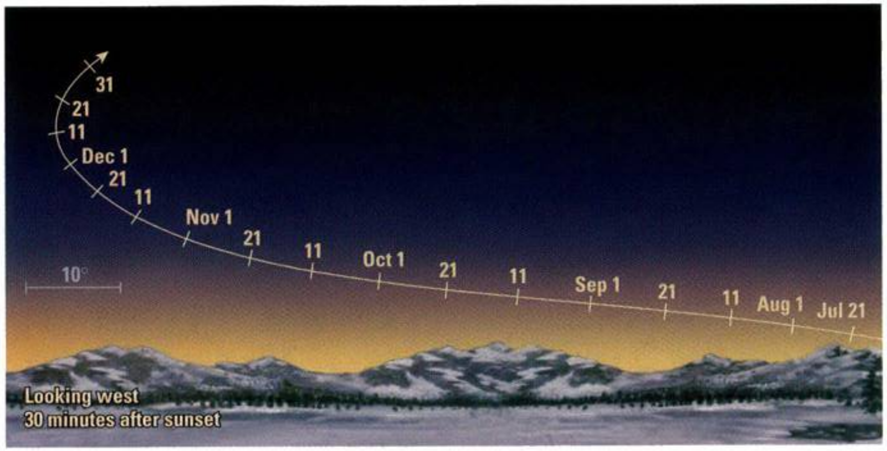
What the planet's disk lacks, the rings more than make up for. The principal detail in the rings visible through most telescopes is the Cassini Division, a narrow gap that separates the outer A Ring from the brighter B Ring. A second, much narrower gap, called the Encke Division, lies in the outer part of the A Ring and can be glimpsed in large backyard scopes under excellent conditions.

Although Saturn's moons pale in comparison to Jupiter's four bright ones, they are still worth viewing. Titan, the largest, orbits the planet once every 16 days. At magnitude 8.3, it's an easy target for any telescope. Larger scopes show five or six additional moons, though they are all significantly dimmer.



Venus and Mars Are All Right Tonight

Nelson Falsarella



Earth's two nearest planetary neighbors, Venus and Mars, have rather pedestrian years to close out the 20th century. Neither reaches any significant milestone, and both spend most of the year relatively near the horizon and fall well short of their peak brightnesses. Yet that doesn't mean the two aren't worth the effort to see. A little patience will prove quite rewarding.

Venus begins the year in the morning sky, rising a healthy three hours before the sun and climbing some 20° above the southeastern horizon by 30 minutes before sunrise. Although this isn't a huge amount of altitude, the saving grace for Venus is its overwhelming brightness. At magnitude −4.1, the planet easily shines through the twilight glow and appears conspicuous in the predawn sky. The waning crescent moon adds to the scene on the morning of January 3, February 2, and March 4.

But throughout this period, Venus is sinking closer to the horizon. By early April, the planet rises barely half an hour before the sun and becomes somewhat difficult to spot. It's disappeared completely by the end of April, when it embarks on a three-month sojourn on the farside of the sun. It returns to the evening sky by early August, when it begins a long, slow climb into the evening twilight that continues through the end of the year.

Conditions improve as the months pass, and by the end of December Venus stands some 30° high half an hour after sunset and shines at magnitude −4.3. If you live in an area with snow on the ground, see if Venus will cast a shadow. Head to a dark location on a night with no moon in the sky and slowly move your hand to and fro. Under ideal conditions, you should glimpse your hand's shadow.

Mars presents more of a challenge this year, but that proves mere prelude to an outstanding 2001. The Red Planet gets no brighter than magnitude 1.0 — bright for a star, perhaps, but pretty lame for everyone's favorite planet. The reason: Mars reaches solar conjunction, when it lies on the farside of the sun from Earth, in the middle of the year and moves so slowly relative to Earth that it never strays far from the sun. Even at year's end, it stands only 35° high an hour before sunrise.

What Mars lacks this year, it makes up for in 2001. By June of that year, the Red Planet comes closer to Earth than at any time since 1988 and puts on a great show. Mars will shine at magnitude −2.4 and display a disk more than 20" across, plenty big enough to show lots of detail in backyard telescopes.

S	M	T	W	T	F	S
			1	2	3	◑
5	6	7	8	9	10	●
12	13	14	15	16	17	◐
19	20	21	22	23	24	○
26	27	28	29	30		

EST

3 **9 A.M.** The moon passes 1.6° south of Neptune

4 **11 A.M.** The moon passes 1.8° south of Uranus

12 **6 A.M.** The moon passes 1.6° south of Saturn
10 P.M. The moon passes 2° south of Jupiter

15 **1 A.M.** Mercury is at greatest western elongation (19°, morning)

17 Leonid meteor shower peaks

19 **8 A.M.** Saturn is at opposition

21 **1 P.M.** The moon passes 4° north of Mars

24 **6 A.M.** The moon passes 3° north of Mercury

27 **9 P.M.** Jupiter is at opposition

29 **1 P.M.** The moon passes 2° north of Venus

30 **5 P.M.** The moon passes 1.8° south of Neptune

DEC

A Christmas Eclipse

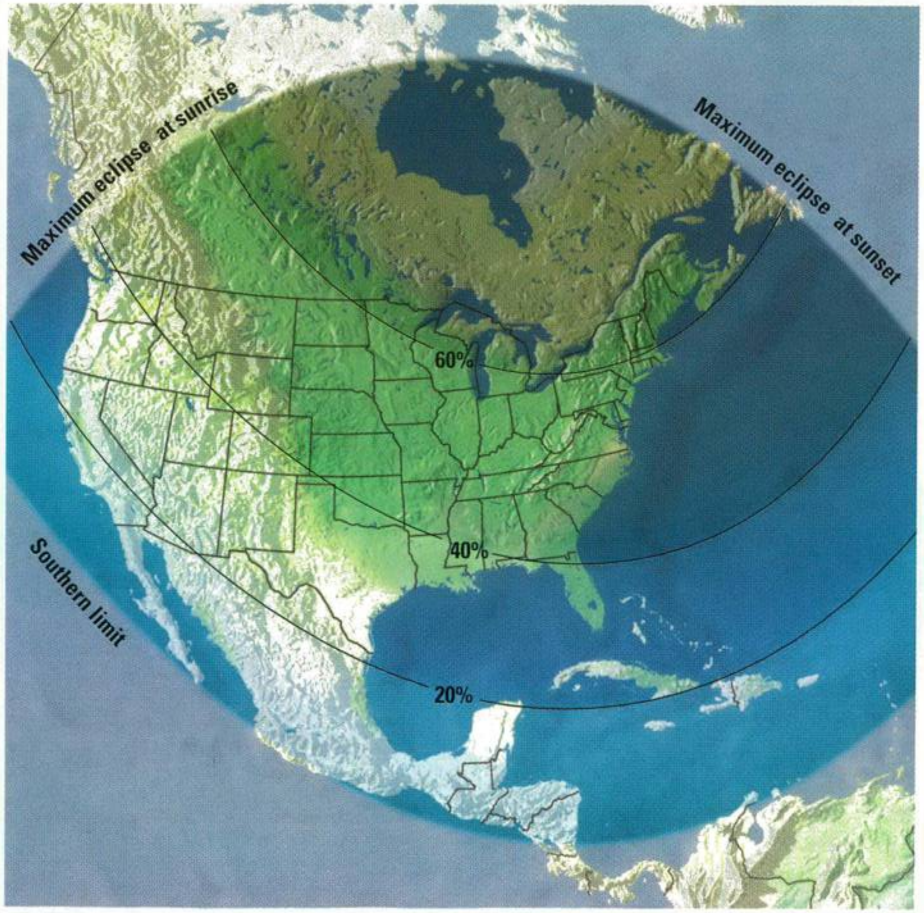
As you take a bite of your Christmas feast or get an early start on that bar of chocolate, the moon will be taking a bite out of the sun. For observers in most of Canada, the United States, Mexico, and the Caribbean, the year's final partial solar eclipse arrives on December 25. The farther north and east your location, the greater the magnitude of the eclipse.

Mark Logan

Those in the far northwestern United States and southwestern Canada will find the eclipse in progress as dawn breaks. By the time the moon's shadow reaches the plains of the Midwest, it will be approaching noon.

But be sure to take precautions if you decide to set up that new Christmas telescope. The only way for a newcomer to safely observe the sun, especially bearing in mind the excitement of owning a new scope, is to project the sun's image onto a white card — which also allows the whole family to watch the progress of the eclipse in complete safety. Use a low-power eyepiece (the one with the longest focal length), align the scope with the sun by minimizing the shadow of the tube on the ground, and eventually you should see the image of the sun appear on the card. You can improve visibility by attaching a larger piece of cardboard to the front end of the telescope (though don't cover the aperture, of course) to create a shadow on the projection screen. Keep in mind that letting anyone view the brilliant sun directly through any optical device will cause permanent eye damage and possibly blindness.

Because the sun is now reaching a peak in solar activity, it's likely that a number of large sunspot groups will be visible. If you compare the relative darkness of the moon's limb with a sunspot as the moon's limb approaches, you'll see the spot appears noticeably grayer.



Exploring the Winter Sky

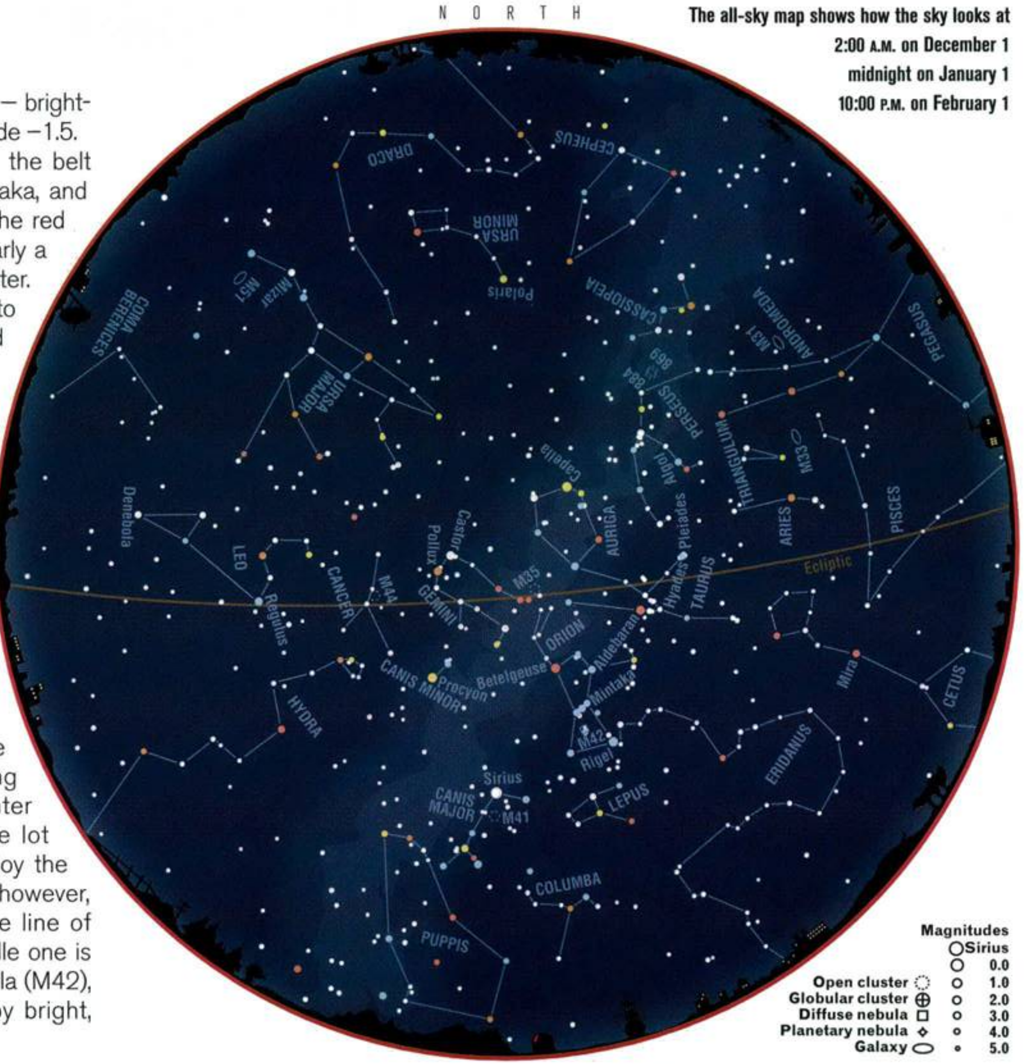
Have you ever become lost in an unfamiliar city or state? Chances are you used two things to get around – a map and some signposts. In much the same way, these two items can help you find your way around the sky in any season. Fortunately, in addition to our seasonal sky charts, there are two major signposts provided for us in the sky. Each seasonal description will talk about the first one – the Big Dipper: a group of seven bright stars in the constellation Ursa Major.

Winter sees the Big Dipper in the northeastern sky, with its triple-starred handle pointing toward the horizon and the four-starred bowl standing highest. The entire sky rotates around a point near Polaris, a 2nd-magnitude star found by extending a line from the uppermost pair of stars in the bowl across the sky to the left of the Dipper.

Turn around with your back to the Dipper and you'll be facing the diamond-studded winter sky. The second great signpost in the sky, Orion the Hunter, is central to the brilliant scene. Three closely spaced 2nd-magnitude stars in a straight line form the unmistakable belt of Orion. Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its orangish 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left and you cannot miss Sirius the Dog Star – brightest in all the heavens at magnitude –1.5.

Now move perpendicular to the belt from its westernmost star, Mintaka, and find at the upper left of Orion the red supergiant star, Betelgeuse, nearly a thousand times the sun's diameter. Continuing this line brings you to a bright pair of stars, Castor and Pollux. Two lines of fainter stars extend from this pair back toward Orion – these represent Gemini the Twins. At the northeastern corner of this constellation lies the beautiful open star cluster M35.

Above Orion and nearly overhead on winter evenings is brilliant Capella in Auriga. Extending a line through the shoulders of Orion to the east leads you to Procyon in Canis Minor. Once you have these principal stars mastered, using our chart to discover the fainter constellations will be a whole lot easier. Take your time, and enjoy the journey. Before leaving Orion, however, aim a pair of binoculars at the line of stars below the belt – the middle one is actually the glorious Orion Nebula (M42), a stellar nursery illuminated by bright, newly formed stars.


N O R T H
DRACO
CEPHEUS
URSA MINOR
Polaris
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
COMA BERENICES
M51
Mizar
URSA MAJOR
869
884
PERSEUS
Algol
TRIANGULUM
M33
Capella
AURIGA
Pleiades
Hyades
TAURUS
ARIES
PISCES
Denebola
LEO
Castor
Pollux
M35
Regulus
CANCER
M44
GEMINI
ORION
Aldebaran
Ecliptic
Mira
CETUS
CANIS MINOR
Procyon
Betelgeuse
Mintaka
HYDRA
M42
Rigel
ERIDANUS
Sirius
CANIS MAJOR
M41
LEPUS
COLUMBA
PUPPIS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows how the sky looks at
2:00 A.M. on December 1
midnight on January 1
10:00 P.M. on February 1

S	M	T	W	T	F	S
					1	2
◑	4	5	6	7	8	9
10	●	12	13	14	15	16
◐	18	19	20	21	22	23
24/31	○	26	27	28	29	30

EST

4 **9 A.M.**
Pluto is in conjunction with the sun

9 **noon**
The moon passes 1.8° south of Saturn

10 **3 A.M.**
The moon passes 3° south of Jupiter
8 P.M.
Mars passes 4° north of Spica (morning)

13 Geminid meteor shower peaks

20 **2 A.M.**
The moon passes 4° north of Mars

21 **9 A.M.**
Solstice (northern winter /southern summer begins)

23 **4 P.M.**
Venus passes 1.3° south of Uranus (evening)

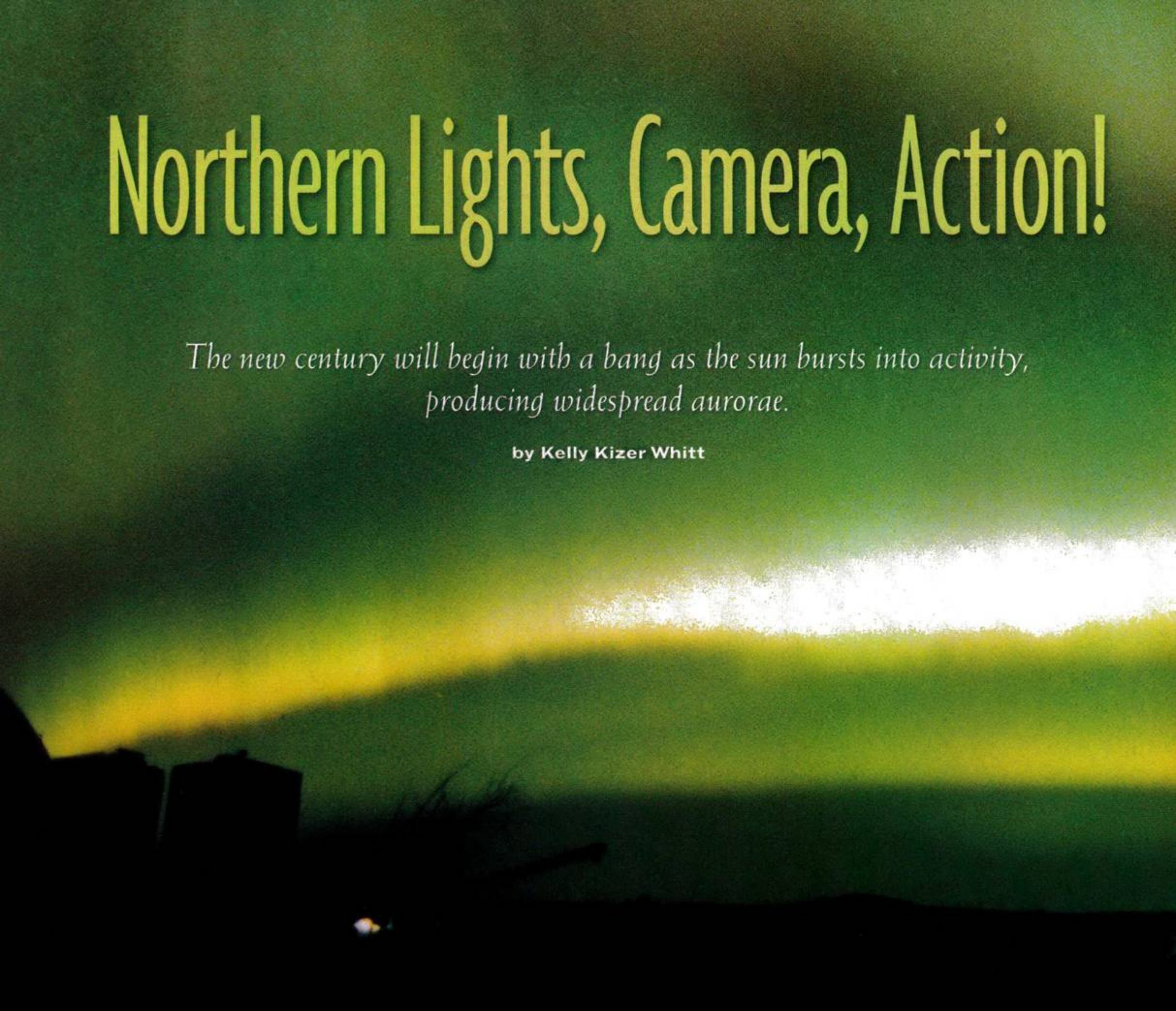
25 **noon**
Partial solar eclipse (visible in most of North America)
2 P.M.
Mercury is in superior conjunction

29 **5 P.M.**
The moon passes 1.8° north of Venus

Northern Lights, Camera, Action!

The new century will begin with a bang as the sun bursts into activity, producing widespread aurorae.

by Kelly Kizer Whitt



An explosion from the sun hurls 10 billion tons of hot plasma toward Earth. The gaseous bubble crosses the vast gulf of space, racing onward at speeds of up to 5 million miles an hour. The cloud of particles expands with distance, until it plows into Earth's atmosphere. And then . . . something beautiful happens. Bright, brilliant aurorae light up the night sky, twisting, waving, and dancing for minutes on end.

The aurora borealis, which is Latin for "northern dawn," should be making a brighter-than-usual appearance in the nighttime skies in the coming year. Aurorae ultimately arise from charged particles (protons and electrons) that have been thrown off the surface of the sun. The rate of this activity reaches a high point every 11 years on average, marking an event known as solar maximum. The last solar maximum occurred in 1989, placing the oncoming 11-year peak around 2000. An active sun at solar maximum gives plenty of opportunities to view the northern lights.

A Time Bomb Waiting to Explode

Those who dabble in solar astronomy easily recognize the oncoming peak of solar maximum. Although astronomers can't literally "see" the reversal in the magnetic polarities that causes the 11-year solar cycle, they can view the effects as the number of sunspots on the surface rises and falls and as sunspots migrate from high latitudes to low. Sunspots mark the most active regions on the sun, areas where solar particles are most likely to be discharged into space.

Three different types of discharges can lead to aurorae on Earth: powerful magnetic explosions called solar flares, a steady stream of charged particles called the solar wind, and spectacular eruptions known as coronal mass ejections. Of the three, coronal mass ejections are by far the most violent, and it's these powerful events that most commonly trigger aurorae at midlatitudes on Earth.

A coronal mass ejection occurs when the solar wind bursts out of a relatively empty region in the sun's outer

Jay Brausch

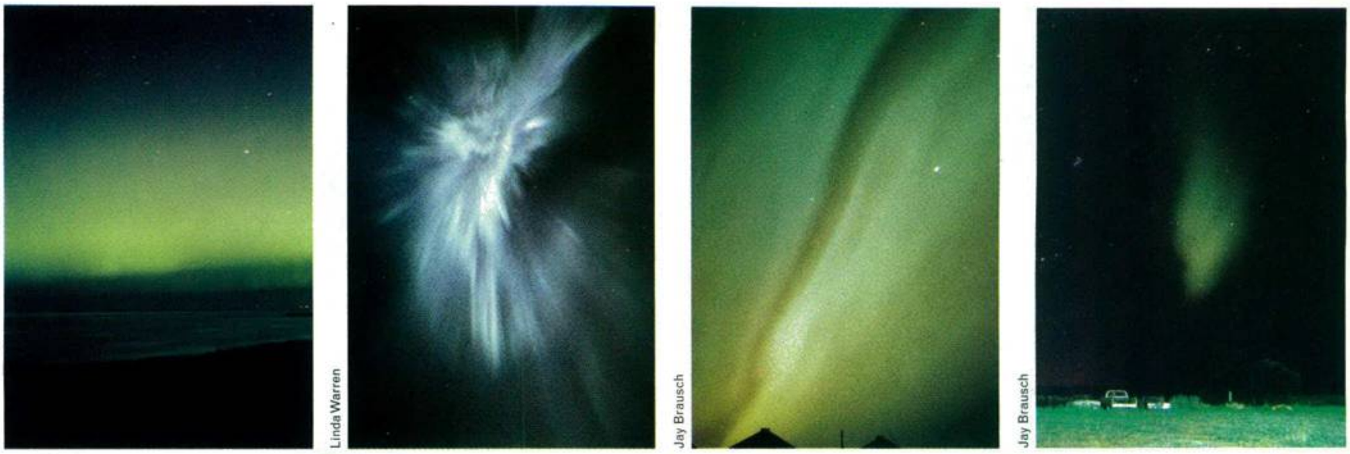
atmosphere, the corona. These ejections contain billions of tons of solar material and cover the millions of miles to our planet in just a few days. In times of solar maximum, two to three coronal mass ejections occur per day, as opposed to one a week during years of solar minimum.

If Earth lies in the path of a coronal mass ejection's debris cloud, the results can be spectacular. "Both the direct magnetospheric effects and the particles can damage spacecraft, endanger the health of spacefarers, and in some cases even induce currents in the Earth and oceans. Some current systems can be strong enough to damage electric power grids," says Joseph Gurman, the U.S. Project Scientist for the Solar and Heliospheric Observatory (SOHO).

Fortunately, Earth's magnetosphere deflects most of the protons and electrons, but some are pulled inward and become trapped, spiraling toward our atmosphere along magnetic field lines until they reach the geomagnetic North and South Poles. This process equally distributes particles between the poles, creating mirror images of aurorae in the Northern and Southern Hemispheres. The Southern Hemisphere version is called the aurora australis.

Once funneled downward by magnetic field lines, the protons and electrons collide with atoms and molecules in Earth's atmosphere at altitudes between 40 and 240 miles (70 and 390 km). The collisions change the internal energy states of the atmospheric atoms and molecules, exciting them to higher levels of energy. As they relax back into their normal states, they release energy in the form of light — photons. When you view an aurora, you are seeing this release of energy.

The higher the energy of the incoming protons and electrons, the deeper they penetrate Earth's atmosphere. This determines the altitude at which the aurora will be produced, which in turn determines the color. At altitudes between 120 and 240 miles, oxygen dominates. Interactions with oxygen at these high altitudes produce all-red



David Armstrong

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Jay Brausch

Jay Brausch

Left to right: The aurora australis seen from New Zealand displays two homogeneous bands. A bluish-white corona moves overhead in Ontario, Canada. A rare black aurora lightens the evening sky near Glen Ullin, North Dakota. Taurus points the way to this auroral patch in North Dakota.

aurorae, the rarest. Very large auroral displays, which reach down to lower latitudes, can also produce shades of vivid red.

Higher-energy interactions with oxygen between 60 and 120 miles in altitude produce aurorae predominantly in hues of green, which is the brightest and most common color. Aurorae contain a mix of red and green colors when interactions occur at a variety of altitudes.

Between 40 and 60 miles, nitrogen reigns supreme. Ionized nitrogen interactions produce bluish light, while neutral nitrogen causes the fringes of the curtains to drip in red. The mixing of the gases or exposure to sunlight or moonlight can cause a variety of outstanding colors, such as purples or pinks.

Seeing the Light

Many factors can increase your odds of seeing aurorae. The most obvious is to be close to or within the auroral oval, a zone extending 1,300 miles (2,100 km) from either geomagnetic pole, where aurorae occur most frequently. The North Geomagnetic Pole doesn't match the North Geographic Pole; it's situated at the northwestern corner of Greenland. This puts the United States at higher geomagnetic latitudes than northern Europe, meaning U.S. observers have better opportunities to view aurorae than their European counterparts at identical latitudes. While aurorae are most frequently seen in the far north and south, extremely active aurorae during solar maximum can sometimes be seen at much lower latitudes. For example, Mexicans saw an aurora in 1989, the previous high in the sunspot cycle.

Aurora Websites

Aurora forecasts

www.sel.noaa.gov/today.html	(NOAA Space Environment Services Center)
dac3.pfrr.alaska.edu/aurora	(University of Alaska)
windows.engin.umich.edu/spaceweather/	(Rice University and WeatherNet 4)
www.spaceweather.com	(The Space Weather Bureau)

Photographing Aurorae

climate.gi.alaska.edu/Curtis/curtis.html	(Jan Curtis)

Auroral sounds

www-pw.physics.uiowa.edu/mcgreevy/	(Stephen P. McGreevy)
www.npr.org/programs/Infsound/onair/990326.onair.html	(National Public Radio)
members.tripod.com/-auroralsounds/	(Swedish Institute of Space Physics)

Location is not the only factor you can control; the time you choose to observe can be just as important. Wait until one and a half hours after sunset so that the skies are dark enough to catch any faint glimmering lights that can't be confused with the sunset. Between midnight and 2 A.M. aurorae are frequently visible as bright, fast-moving lights. Clear nights are essential, and they usually occur when the outside air is cold. March and September are the two best months for viewing aurorae. If you are too far north, summer is a bad time of year because the sky never gets dark enough.

Various sources predict aurorae. You can use your own magnetometer at home to detect geomagnetic disturbances. The National Oceanic and Atmospheric Administration's Space Environment Services Center in Boulder, Colorado, plays a recorded message of 24-hour forecasts for geomagnetic disturbances and active areas on the sun. Access this message by calling (303) 497-3235. This forecast is also available over the Internet (see Aurora Websites below). Other good websites for aurora forecasts are listed in the same box.

If you miss out on seeing a spectacular auroral display, don't fret — you may get a second chance. Occasionally a big display is followed by another 27 days later due to the rotation period of the sun, because an active region can open up a coronal hole that can persist for months.

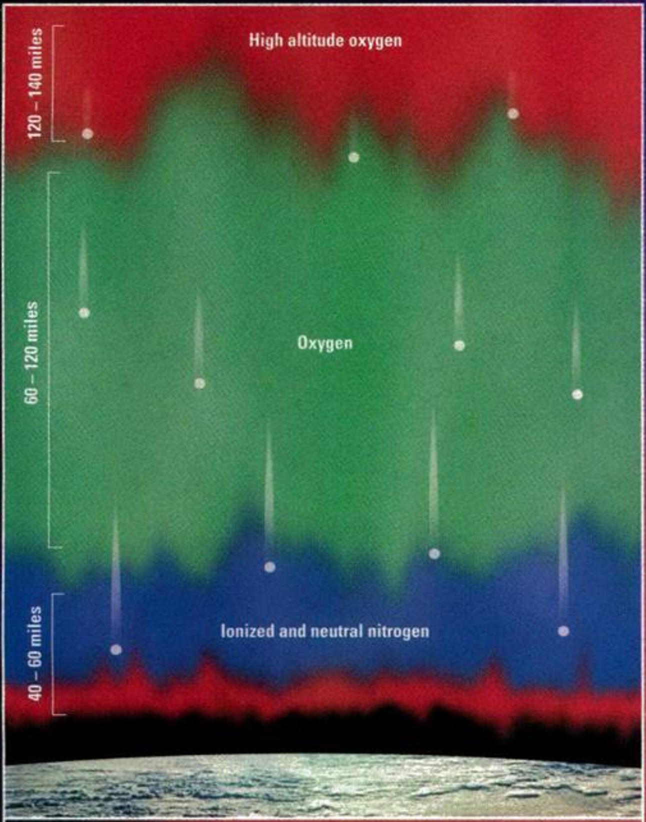
The Form of the Storm

When the odds all come together in your favor, you probably won't be disappointed. Unlike television, Mother Nature doesn't air reruns. Every auroral display you see will be unique, whether it's due to color, intensity, duration, or shape. Many words are used to describe the forms and shapes that occur during an auroral display. But different characteristics of aurorae have specific names, and once you learn them, you can identify the types of aurorae you've seen.

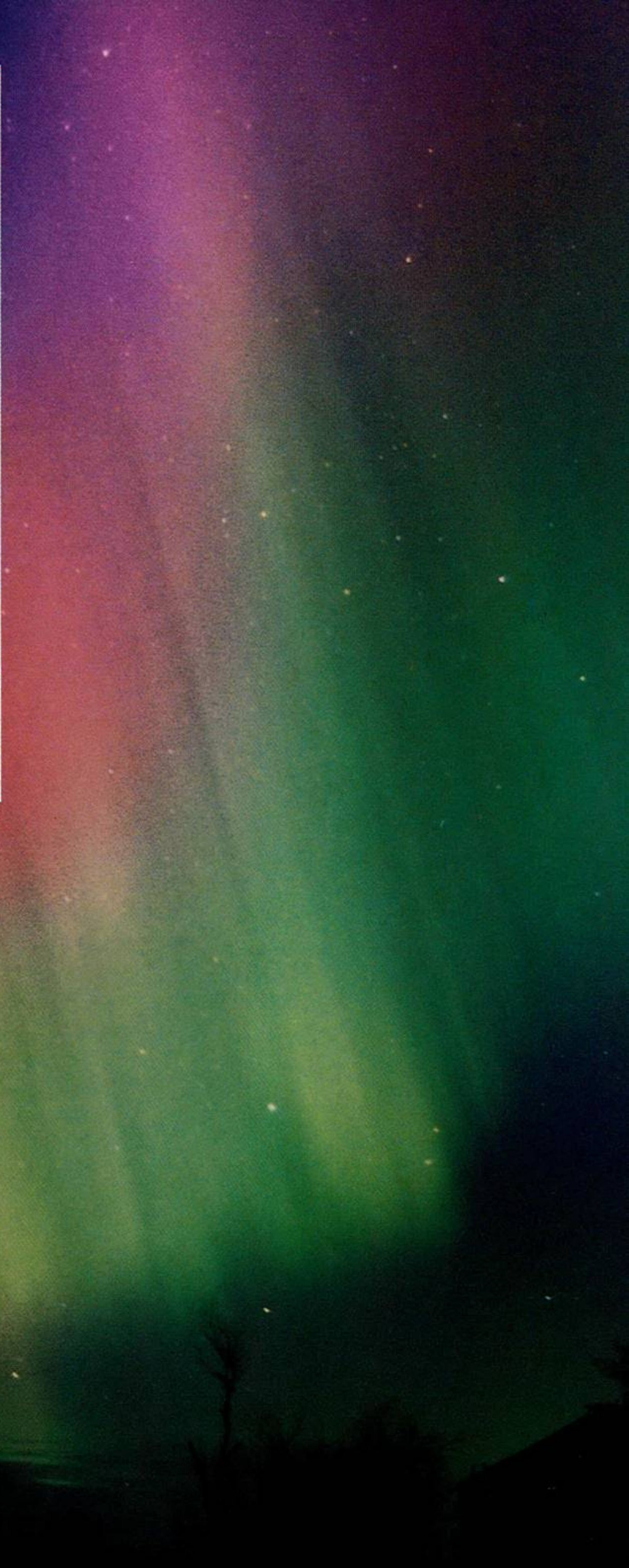
"Glows" are diffuse auroral lights with no apparent structure. They can be difficult to distinguish from sunsets or distant city lights reflected in the sky. "Patches," sometimes called "surfaces," are small, cloud-like apparitions that brighten and fade. Both glows and patches generally have weak colors.

When people use the words "streamers" or "curtains" to describe aurorae, they've probably seen "arcs" and "bands" — the most common form of aurorae. An arc is a slightly

Photo by Jay Brausch / Illustration by Terri Field/*Astronomy*


High altitude oxygen
120 – 140 miles
Oxygen
60 – 120 miles
Ionized and neutral nitrogen
40 – 60 miles

The color of an aurora depends on what altitude and type of gas is being stimulated by solar particles. More energetic particles penetrate to deeper levels.



Joshua Vaughan

curving aurora that extends across the sky and has smooth bottom borders. A band appears the same except that its borders are irregular or curving.

Arcs and bands are frequently modified by the words "homogeneous" or "rayed." Homogeneous arcs or bands show little activity, whereas rayed shapes are more active. Rays appear to be smeared vertically against the heavens. When the bands take on loops and whorls, folding into circular patterns, they are said to be "surging." Any of these forms appearing nearly overhead are called corona. Coronae are an effect of perspective. What looks like a corona in North Dakota might look like a rayed band in South Dakota.

A very rare "veil" aurora appears as an extensive, uniform luminosity across the sky. If a veil is present but has small holes where the dark sky seeps through, it is called a "black aurora," even though the black holes are pockets where the aurora is absent. A black aurora looks as if it is a photo negative of a regular aurora.

Toward the end of an auroral display, the lights may dim and disappear, then weakly reappear, and disappear again. The aurora is said to be "pulsating," and pulsation can last for hours until the display finally diminishes or the sun rises.

Once you see an aurora, you may want to preserve it on film. Jan Curtis, who works at the Geophysical Institute in Fairbanks, Alaska, has his own website called Home of the Northern Lights (see Aurora Websites), where he shares a multitude of images he has taken of the aurorae.

For the novice aurora photographer, Curtis recommends 400 speed film with a 35mm camera on a tripod equipped with a cable release. Use a wide-angle 24mm to 50mm lens and set the camera to the fastest f/stop (or one stop slower) to avoid distortion of bright star images. Exposures of 5 to 15 seconds work well depending on the speed and brightness of the aurora. "People tend to overexpose their photos," says Curtis. He advises to limit moonlight and city lights as much as possible, but adds, "Auroral displays are unpredictable, so patience is the key."

The color of the aurora you see with your eyes can differ markedly from the colors in your photographs, which depend greatly on the film's sensitivity. If you process your own photographs with a computer program such as Adobe Photoshop, you can emphasize and manipulate the resulting hues.

Snap, Crackle, Pop

From 2,000-year-old records of Germanic people to present-day observers, people have claimed to have heard aurorae. The reports are similar. Some say it is a hissing sound; others say it is a crackling or a rustling noise, using such words as "swish," "sizzle," "pop," and "whoosh" to describe their experiences.

Russ Sampson

Above: An all-red auroral glow provides an unusual backdrop for Red Rock Crossing in Sedona, Arizona, in 1989. Left: Surging rayed bands dance beside Jupiter and Venus over the bright city lights of Edmonton, Canada.

No single explanation has yet proved how aurorae can generate sounds. The domain of the aurora is 40 miles high at its closest point to the surface. The air that high up is just too thin to carry sound waves. Even if sound waves could be generated up there, it would take several minutes for those sounds to propagate down to our altitude.

Scientists have proposed a number of ideas. Some dismiss the phenomenon as simply tinnitus (the ringing in a person's ears). Alternatively, some aurora experts subscribe to the "it's all in your head" theory, meaning a person's mind simply fills in audible sounds it thinks it would hear to accompany such a visual display. But two popular notions, coronal (or brush) discharge and geophysical electrophonics, have become the leading scientific explanations.

The theory of coronal discharge was suggested 40 years ago by Norwegian aurora expert Carl Störmer. On nights with strong aurorae, the electrical field near the ground can be 15 times stronger than normal. These powerful electrical fields can ionize molecules in the air, meaning they strip the molecules of their electrons. This so-called coronal discharge can give rise to a rustling or hissing sound.

Colin Keay of the University of Newcastle in Australia first proposed the idea of geophysical electrophonics in 1980. Keay was attempting to explain the sounds of both aurorae and meteoric fireballs. Space-based satellites and ground-based antennae have detected low frequency radio waves generated at very high altitudes in connection with both aurorae and fireballs. The energy of these radio waves can be transferred into sound waves by something as simple as trees, clothing, or even the hairs in a person's ear. Often one person hears the aurora while someone in close proximity does not.

Whether you hear aurorae or not, a colorful show of lights and phantom sounds are awaiting you this year. Now that you are familiar with the cast of characters, sit back and enjoy the show as the curtain rises on another memorable aurora season.

Kelly Kizer Whitt, copy editor of Astronomy *magazine, has occasionally seen, but never heard, the northern lights.*

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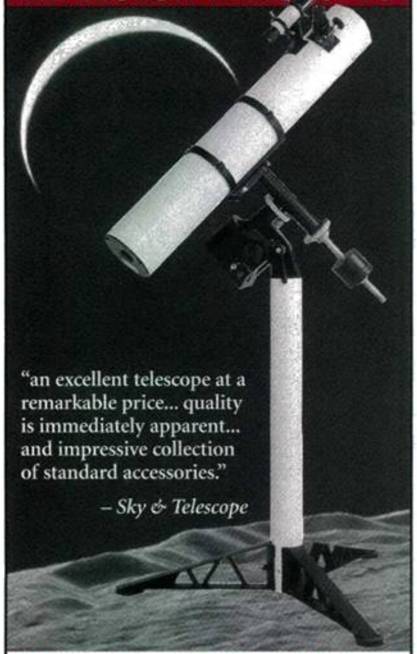

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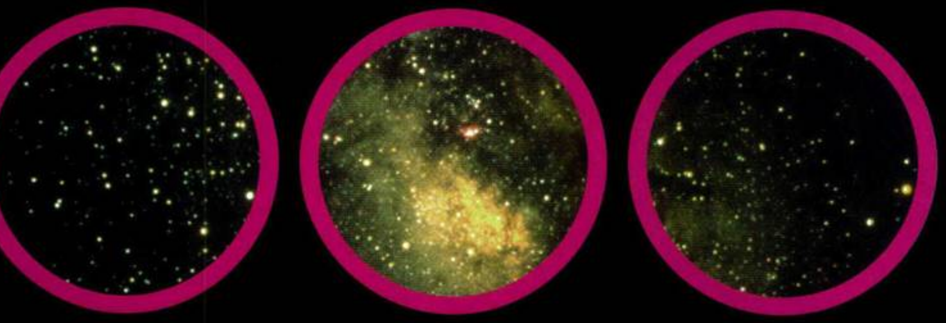
ASTRONOMY'S 2000 BUYER'S GUIDE TO TELESCOPES AND BINOCULARS



The profusion of astronomical equipment can leave buyers confused and weary. We offer a guide to help you cut through the hype.

by Phil Harrington

Few things are more exciting for an amateur astronomer than contemplating the purchase of a telescope. Many who are new to the hobby immediately want to dive in and purchase a telescope. The excitement is understandable, and selecting that first (or second) scope is an important step in your quest to comprehend the universe. One quick glance through a catalog reveals many telescopes from which to choose. Which is best for you? How much do you really have to spend to get a good telescope? And perhaps even more importantly, do you really need a telescope?

STEP ONE: LEARN TO WALK BEFORE YOU RUN

Many first-time stargazers jump into the purchase too quickly, buying before they really know the sky. The best advice I can offer: Don't rush into purchasing a telescope. Newcomers should begin their journey by learning the appearance of the major constellations and the names of the brighter stars. If you can't see sights with your eyes alone, how can you expect to recognize targets in a magnified view?

Take at least six months to become familiar with the stars. Go out every chance you get and pick out a new star or constellation. Above all, don't rush. The stars have been there for billions of years; they'll still be there after you have learned your way through the cosmos.

STEP TWO: BINOCULARS

Even after you've taken time to learn the naked-eye sky, it might be best to put off buying a telescope. Instead, pick up a pair of binoculars. They are portable, easy to use, and let you observe in a more natural way, with both eyes.

Binoculars are rated by two numbers separated by an x (e.g. 7x35, which is read "seven by thirty-five"). The first number is the magnification, while the second refers to the aperture, or the diameter of the front objective lenses, in millimeters. Low-power binoculars (7x to 10x) are great for wide-field views of the Milky Way, but higher-power glasses (11x and above) are preferred for solar system objects such as the moon, sun, and planets.

Choosing an aperture is just as important as deciding on the magnification. Together, they regulate the exit pupil, or the diameter of the beam of light exiting the binoculars' eyepieces. For optimum performance, the exit pupil should equal your pupil's diameter. If you are younger than 30 and spend most of your observing time under dark rural skies, then your pupils should dilate fully to about 7 mm. If your location suffers from light pollution or you are older than 30, your pupils may never dilate beyond 5 or 6 mm. Your ideal binoculars' exit pupil should be sized accordingly.

To find the exit pupil of a pair of binoculars, simply divide the objective's diameter by the power. A pair of 7x50 binoculars have a 7.1 mm exit pupil (50 ÷ 7 = 7.1), while 10x50 glasses have a 5 mm exit pupil.

Also keep in mind that as magnification and aperture increase, so does the binoculars' weight. This is especially important if you plan on supporting the glasses by hand. Most people can support up to 50mm binoculars with minimal strain and fatigue. Larger binoculars are best mounted on a tripod or other support.

The majority of the binoculars listed are porro prism models. They feature the familiar zigzag barrel design. Roof-prism binoculars are characterized by their sleek, straight barrels and are often inferior to porro-prism models due to their typically small apertures. Some top-of-the-line roof-prism models are included, but most have been bypassed in favor of their more astronomically worthy cousins.

Better binoculars have prisms of BaK-4 glass, which has better light-transmission properties that produce brighter and sharper images. The type of glass may be printed somewhere on the binoculars themselves. Hold the binoculars at arm's length and look at the exit pupils, the circles of light coming out of each eyepiece. Are they both clear circles, or do you notice a diamond shape within? Clear circles indicate that the pair's prisms are made of BaK-4 glass, while the diamond effect indicates cheaper BK-7 prisms.

Check to see if the lenses are coated, fully coated, multicoated, or fully multicoated. Single-coated optics greatly reduce flare (stray light) and increase image contrast. Multicoated optics suppress flare and improve contrast, while fully coated optics (each optical surface is coated with a microscopically thin layer of magnesium fluoride) are better still. The finest binoculars are fully multicoated — the coatings are built up in thinner layers on each optical surface. They cost more but are usually worth the price.

Binocular eyepieces are either focused individually or focused in tandem by turning a center wheel. Individual focusing eyepieces yield sharp images, though some observers find them more difficult to hold and focus at the same time. Center-focus binoculars are very convenient, but always check to make sure the mechanism does not bind throughout the focus range. Less-expensive center-focus binoculars often use a fast-focus lever rather than a thumb wheel. These are not as suitable for astronomical viewing since they do not focus as precisely.

Do the binoculars have a center tripod socket? While many people hold binoculars by hand, I strongly recommend that you place them on a substantial camera tripod or special binocular mount. This makes going from a star chart to eyepiece easier.

Literally thousands of binoculars flood the consumer market today. Some are better for birdwatching or viewing distant terrestrial sights, while others are best taken to the theater or a sporting event. The accompanying table lists over 300 current models that are judged to be among those suitable for astronomical viewing.

STEP 3: CHOOSING A TELESCOPE

Okay, you've learned the sky both naked eye and with binoculars, and you're ready for a telescope. But which telescope? There are so many different types and sizes, some with complex, computerized accessories, others standing taller than most astronomers. Which is right for you?

Telescopes come in one of three basic designs: the refractor, the reflector, and the catadioptric. A refractor is recognizable by its long, thin tube and features a large objective lens in the front. The observer looks through a small lens (the eyepiece) at the back end of the tube.

Reflecting telescopes use large primary mirrors at the bottom of their tubes to gather light and bring it to a focus. Though it may look flat, the primary is actually concave, curved ever so slightly inward, like a bowl. The most popular type of reflecting telescope, the Newtonian reflector, was invented by Sir Isaac Newton in 1672. In a Newtonian, light strikes the primary mirror and reflects to a small, flat secondary mirror (the diagonal) tilted at 45 degrees. The light then bounces off the secondary at a 90° angle, out through a hole in the side of the tube, and into an eyepiece.

Digital Stock

The third type of telescope is a refractor/reflector hybrid called a catadioptric. Light passes through a large corrector plate to the primary mirror at the back of the tube. Bouncing off the primary mirror, the light reflects toward the front of the telescope. From here, one of two things can happen. The light can reflect off a convex secondary mirror, through a hole in the primary, and out to the eyepiece. Or, it can take the less common route of Newtonian-style catadioptrics. In a Newtonian-style catadioptric, the light hits a diagonal mirror that redirects the light through the side of the tube and into the eyepiece.

All telescopes, regardless of type, share many common functions and terms. For instance, aperture is the diameter of the instrument's main optic and refers to the telescope's size. Telescope length typically depends on the focal length of that main optic, or the distance it takes light to come to a focus after striking the lens or mirror. Then there is the focal ratio, which is the instrument's focal length divided by its aperture. A 6-inch telescope with a 48-inch focal length has a 6-inch diameter mirror and a focal ratio of f/8 ($48 \div 6 = 8$).

How about magnification or power? Many first-time buyers believe this to be the most important factor — the greater the magnification, the better the telescope. In reality, nothing could be further from the truth. Any telescope can operate at any magnification just by changing the eyepiece. However, higher magnification isn't always a good thing. Keep in mind this general rule, do not exceed a magnification of 50x per inch of aperture, up to a magnification of 300x. Surpassing this limit generally causes the focused image to lose most of its clarity and sharpness. Magnification is easy to calculate. Divide the focal length of a telescope by the focal length of the eyepiece being used (it's usually printed on the barrel or along the upper rim).

Instead of worrying about magnification, buy the largest aperture you can afford and handle. Keep in mind that large telescopes are much more difficult and time-consuming to transport and set up than smaller instruments. I know people who own huge telescopes but rarely use them. They are too heavy and cumbersome. Think about how you'll store and move the telescope before deciding what to buy. The accompanying table itemizes this quality as ease of setup.

Check the sturdiness of the telescope's mounting. Even the finest scope will be unusable if its mount wobbles in the breeze. Altitude-azimuth mounts, which move a telescope up-and-down and left-to-right, are often supplied on less expensive telescopes. The more expensive instruments feature equatorial mounts, which move in one fluid motion with the stars.

Many of the largest Newtonian reflectors are supported by a variation of the altitude-azimuth mount called a Dobsonian mount. Though simple in design, Dobsonians are often more stable than equatorial mounts. This makes them ideal for visual observations and even simple astrophotography. For those looking to do long-exposure astro-imaging, equatorial mounts are a must.

Ease of use is also an important consideration. The listings judge this parameter based on the telescope, mounting, and accessories. If this is your first telescope, pay close attention to the standard accessories. Often, the cheapest telescope is not the least expensive when you figure in the additional cost of extra eyepieces and other necessities. Some telescopes come complete with finderscopes, eyepieces, mountings, and other accessories. If so, then their ease of use is based on these standard accessories. In instances where the telescope comes without these key ingredients, the ease of use assumes that the user has outfitted the telescope with accessories necessary to use the instrument.

Eyepieces and finders are important considerations when selecting a telescope. Small finders, such as the 5x24 models supplied with some less-expensive instruments, are practically useless. The 6x30 finders are adequate for aiming at brighter sky objects such as the moon and planets. If you crave faint deep-sky objects, then an 8x50 finder should be your smallest choice.

Eyepieces come in many shapes and sizes, but all have one of three barrel diameters, 0.965, 1.25, or 2 inches. A well-established standard is the 1.25-inch barrel. Some imported instruments use smaller, 0.965-inch diameter eyepieces. These are almost always inferior and should be avoided. Many top-of-the-line instruments can also accept 2-inch eyepieces. These are considered the cream of the crop and therefore may cost more than some fully loaded telescopes.

Kellner eyepieces (or variations called MA and SMA eyepieces) are often supplied as standard equipment. These are fine to start with, but most observers will outgrow them rapidly. Other telescopes come with far superior Plössl eyepieces. These should provide a lifetime of use. Be sure to consider the cost of a few new eyepieces when selecting your telescope.

A quick glance at the table finds some of the largest telescopes scoring rather low in "ease of set up" and "ease of use." These ratings were given because of the telescope's size and height. In some instances, an observer must scale a 10-foot ladder to get to the eyepiece. It's difficult to compare ease of use for a 4-inch refractor versus a 25-inch Newtonian. The 4-inch refractor will be, by its size, easier to set up and use, but the 25 inch will produce far superior views by its larger aperture. You would do best to compare like telescopes with like telescopes, apples with apples, and oranges with oranges.

The table also lists typical delivery time and typical retail price, both of which can vary greatly. Delivery time is especially difficult to judge. If the instrument is purchased from a local dealer, delivery time depends on a dealer's stock. The telescopes listed as available "from stock*" (with the asterisk) may still take months to get. Price from one dealer to another may also differ, and keep in mind that the least expensive price is not necessarily the cheapest once you figure in shipping and handling expenses. My best suggestion is to call several dealers to check availability and pricing before placing an order.

To get even more insight into which instrument might be right for you, consider joining a local astronomy club. Local museums, nature centers, and perhaps even better camera stores can put you in touch with a group in your area. By speaking with owners directly, you can learn an instrument's strengths and weaknesses. Most clubs also have observing parties where you can take a look through several different instruments to compare views. With a little patience and effort, you'll soon be on your way to the ultimate instrument for your needs. ▣

Phil Harrington is the author of five books for the amateur astronomer, including Star Ware: The Amateur Astronomer's Ultimate Guide to Choosing, Buying, and Using Telescopes and Accessories. *Visit his home page at http://ourworld.compuserve.com/homepages/pharrington.*

TELESCOPES

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ACHROMATIC REFRACTORS									
Celestron Novice 50	2	12	Aluminum	Alt-az	5	5	1	From stock*	$80
Celestron Novice 60	2.4	12	Aluminum	Alt-az	7	5	1	From stock*	$100
Celestron Firstscope	2.4	12	Aluminum	Alt-az	7	5	1	From stock*	$110
Celestron Firstscope	2.4	12	Aluminum	Alt-az	7	5	2	From stock*	$140
Celestron Firstscope	2.4	12	Aluminum	Alt-az	7	5	2	From stock*	$150
Celestron Firstscope	2.4	15	Aluminum	Alt-az	6	5	1	From stock*	$110
Celestron Firstscope	2.4	12	Aluminum	GEM	11	5	2	From stock*	$160
Celestron Firstscope	2.4	12	Aluminum	GEM	11	5	2	From stock*	$180
Celestron Firstscope 60 EQ	2.4	12	Aluminum	GEM	11	5	2	From stock*	$190
Celestron Firstscope 60	2.4	15	Aluminum	GEM	9	5	2	From stock*	$190
Celestron Firstscope 70 AZ	2.8	13	Aluminum	Alt-az	12	5	2	From stock*	$220
Celestron Firstscope 70 EQ	2.8	13	Aluminum	GEM	17	5	3	From stock*	$240
Celestron Firstscope 80 AZ	3.1	11	Aluminum	Alt-az	18	5	3	From stock*	$310
Celestron Firstscope 80 EQ	3.1	11	Aluminum	GEM	24	5	4	From stock*	$350
Celestron Firstscope 80	3.1	5	Aluminum	GEM	13	5	5	From stock*	$300
Celestron C80-HD	3.1	11	Aluminum	GEM	29	5	4	From stock*	$500
Celestron C102-AZ	4	10	Aluminum	Alt-az	28	5	3	From stock*	$570
Celestron C102-HD	4	10	Aluminum	GEM	36	5	4	From stock*	$670
Edmund 60MM	2.4	8	Aluminum	Fork	10	5	3	From stock*	$450
Hands-On-Optics Montana 120	4.7	8.3	Aluminum	GEM	37	5	4	From stock–2 weeks	$850
Meade 102ACHR/300	4	9	Aluminum	GEM	N/S	5	4	From stock*	$600
Meade 102ACHR/500	4	9	Aluminum	GEM	N/S	5	4	From stock*	$700
Meade 230	2.4	11.7	Aluminum	Alt-az	7	5	2	From stock*	$190
Meade 285	2.4	15	Aluminum	GEM	20	5	2	From stock*	$300
Meade 390	3.5	11	Aluminum	Alt-az	17	5	3	From stock*	$530
Meade 395	3.5	11	Aluminum	GEM	27	5	3	From stock*	$630
Orion Observer 60 Alt-Az	2.4	11.7	Aluminum	Alt-az	N/S	5	2	From stock	$100
Orion Observer 60 EQ	2.4	15	Aluminum	GEM	N/S	5	2	From stock	$180
Orion Observer 60 EQ Ultra	2.4	15	Aluminum	GEM	N/S	5	3	From stock	$250
Orion Observer 60 Ultra	2.4	13.3	Aluminum	Alt-az	N/S	5	3	From stock	$160
Orion Observer 70 Alt-Az	2.8	10	Aluminum	Alt-az	N/S	5	2	From stock	$200
Orion Observer 70 EQ	2.8	10	Aluminum	GEM	N/S	5	2	From stock	$250
Orion Observer 80 EQ Ultra	3.1	11.3	Aluminum	GEM	N/S	5	3	From stock	$350
Orion ShortTube 80	3.1	5	Aluminum	SS	N/S	5	5	From stock	$250
Orion SkyView Deluxe 90	3.5	11.1	Aluminum	GEM	32	5	4	From stock	$560
Orion/Vixen VX102 GP	4	9.8	Aluminum	GEM	48	5	4	From stock	$1,200
Orion/Vixen VX80	3.1	11.4	Aluminum	Alt-az	N/S	5	4	From stock	$560
Parks PRT-1	2.4	11.7	Aluminum	Alt-az	8	5	2	3 months	$300
Parks PRT-2	2.4	11.7	Aluminum	Alt-az	8	5	2	3 months	$400
Parks PRT-46	2.4	15.2	Aluminum	GEM	11	5	2	3 months	$500
Parks PRT-813	3.1	11.2	Aluminum	GEM	24	5	3	3 months	$700
Unitron Model 128	2.4	15	Aluminum	GEM	24	5	2	90 Days	$2,800

Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
Unitron Model 142	3	16	Aluminum	GEM	46	4	3	90 Days	$3,300
Unitron Model 152	4	15	Aluminum	GEM	100	3	3	90 Days	$4,300
APOCHROMATIC REFRACTORS									
APM Triplet Zero color-Apo 80/480	3.1	6	Aluminum	SS	N/A	5	5	From stock*	$1,600
APM Triplet Zero color-Apo 80/600	3.1	7.5	Aluminum	SS	N/A	5	5	From stock*	$1,200
APM Triplet Zero color-Apo 105/650	4.1	6.2	Aluminum	SS	N/A	5	5	From stock*	$3,200
APM Triplet Zero color-Apo 100/800	3.9	8	Aluminum	SS	N/A	5	5	From stock*	$2,700
APM Triplet Fluorite 5	5	7	Aluminum (CF)	SS	N/A	4	5	12 months	$6,500
APM Triplet SDT 130/780	5.1	6	Aluminum (CF)	SS	N/A	5	5	2 months	$5,500
APM Doublet Fluorite 6	6	9	Aluminum (CF)	SS	N/A	4	5	12–24 months	$8,200
APM Triplet SDT 150/900	6	6	Aluminum (CF)	SS	N/A	5	5	3 months	$7,400
APM Triplet SDT 152/1200	6	7.9	Aluminum (CF)	SS	N/A	4	5	3 months	$7,400
APM Doublet Fluorite 7	7	9.5	Aluminum (CF)	SS	N/A	3	4	12–36 months	$11,500
APM Triplet SDT 180/1440	7.1	8	Aluminum (CF)	SS	N/A	3	4	7 months	$11,500
APM Doublet Fluorite 8	8	10	Aluminum (CF)	SS	N/A	2	4	12–24 months	$22,000
APM Fluorite 8	8	6	Aluminum (CF)	SS	N/A	3	4	15–18 months	$22,000
APM Triplet Fluorite 8	8	8	Aluminum (CF)	SS	N/A	3	3	12–24 months	$27,000
APM Triplet SDT 200/1830	8	9	Aluminum (CF)	SS	N/A	2	3	6–10 months	$22,000
APM Triplet SDT 9	9	9	Aluminum (CF)	SS	N/A	2**	3	12–15 months	$30,000
APM Triplet Fluorite 10	10	9	Aluminum (CF)	SS	N/A	1**	3	15–20 months	$44,000
APM Triplet SDT 12	12	9	Aluminum (CF)	SS	N/A	1**	3	8–12 months	$60,000
APM Doublet Fluorite 12	12	10	Aluminum (CF)	SS	N/A	1**	3	15–18 months	$85,000
APM Doublet SDT 16	16	15	Aluminum (CF)	SS	N/A	1**	3	6–8 months	$150,000
Astro-Physics 105EDFS (Traveler)	4.1	6	Aluminum	SS	N/A	5	5	10–12 months	$2,400
Astro-Physics 130EDFS	5.1	6	Aluminum	SS	N/A	5	5	10–12 months	$3,250
Astro-Physics 155EDF	6.1	7	Aluminum	SS	N/A	4	5	10–12 months	$6,800
Astro-Physics 155EDFS	6.1	7	Aluminum	SS	N/A	4	5	10–12 months	$4,900
Meade 102APO/500	4	9	Aluminum	GEM	N/S	5	5	From stock*	$700
Meade Apochromatic 102ED	4	9	Aluminum	GEM	69	5	5	5–6 months	$2,800
Meade Apochromatic 127ED	5	9	Aluminum	GEM	78	4	5	5–6 months	$3,300
Meade Apochromatic 152ED	6	9	Aluminum	GEM	153	4	5	5–6 months	$5,000
Meade Apochromatic 178ED	7	9	Aluminum	GEM	176	3	4	5–6 months	$6,000
Orion/Vixen VX80 Fluorite	3.1	8	Aluminum	SS	N/S	5	4	5–6 months	$6,000
Orion/Vixen VX102-ED GP	4	6.5	Aluminum	GEM	40	5	4	From stock	$1,900
Orion/Vixen VX102-FL GP	4	9	Aluminum	GEM	46	5	4	From stock	$2,500
Orion/Vixen VX120 GP (semi-apochromatic)	4.7	6.7	Aluminum	GEM	48	4	5	From stock	$2,000
Takahashi FC-60	2.4	8.3	Aluminum	GEM	27	5	3	From stock–1 month	$ 3,100
Takahashi FS-78	3	8	Aluminum	GEM	30	5	4	From stock–1 month	$4,300
Takahashi FS-102	4	8	Aluminum	GEM	35	5	5	From stock–1 month	$5,000
Takahashi FSQ-106	4.2	5	Aluminum	SS	N/S	5	5	From stock–1 month	$3,200
Takahashi FS-128	5	8.1	Aluminum	GEM	41	4	5	From stock–1 month	$10,000
Takahashi FS-152	6	8.1	Aluminum	GEM	109	4	5	From stock–2 months	$14,700
Takahashi FCT-150	6	7	Aluminum	GEM	187	4	5	3 months	$27,000

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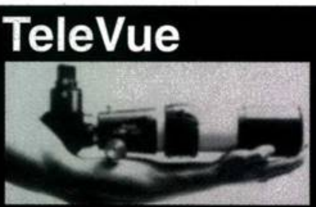
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Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
Takahashi FCT-200	8	10	Aluminum	GEM	N/S	2**	3	3 months	$197,000
Tele Vue Bizarro	3.3	7	Aluminum	SS	8	5	5	From stock*	$2,900
Tele Vue Pronto (semi-apochromatic)	2.8	6.8	Aluminum	SS	6	5	5	From stock*	$1,080
Tele Vue Ranger (semi-apochromatic)	2.8	6.8	Aluminum or brass	SS	6	5	5	From stock*	$700
Tele Vue TV-85	3.3	7	Aluminum	SS	8	5	5	From stock*	$2,000
Tele Vue TV-101	4	5.4	Aluminum	SS	N/A	5	5	From stock*	$2,760
Yeier Optics AP080	3.1	6	Aluminum	SS	N/A	5	5	Up to one year	$1,500
NEWTONIAN REFLECTORS									
Celestron Tabletop 76	3	8	Unknown	Alt-az	N/S	5	1	From stock*	$120
Celestron Firstscope 76 AZ	3	9	Unknown	Alt-az	13	5	2	From stock*	$100
Celestron Firstscope 76 EQ	3	9	Unknown	GEM	15	5	2	From stock*	$160
Celestron Firstscope 114	4.5	9	Aluminum	GEM	19	5	2	From stock*	$250
Celestron Firstscope 114 Deluxe	4.5	9	Aluminum	GEM	19	5	2	From stock*	$300
Celestron Firstscope 114 Premium	4.5	9	Aluminum	GEM	19	5	3	From stock*	$350
Celestron Firstscope 114 Short	4.5	9	Aluminum	GEM	16	5	2	From stock*	$230
Celestron Firstscope C114-HD	4.5	8	Aluminum	GEM	28	5	4	From stock*	$450
Celestron Star Hopper 4.5	4.5	8	Aluminum	Alt-az	20	5	4	From stock*	$240
Celestron C150-HD	6	7	Aluminum	GEM	41	5	4	From stock*	$660
Celestron Star Hopper 6	6	8	Cardboard	Dob	44	5	5	From stock*	$430
Celestron Star Hopper 8	8	6	Cardboard	Dob	62	4	5	From stock*	$540
Celestron Star Hopper 11	11	4.5	Cardboard	Dob	95	3	4	From stock–2 months*	$900
Celestron Star Hopper 14	14	4.5	Cardboard	Dob	135	2	4	From stock–2 months*	$1,200
Celestron Star Hopper 17.5	17.5	4.1	Cardboard	Dob	225	1	3	From stock–2 months*	$2,200
Coulter Odyssey 8	8	4.5 or 7	Cardboard	Dob	39 or 59	5	2	6–12 months	$400
Coulter Odyssey 10	10.1	4.5 or 5.6	Cardboard	Dob	65 or 69	4	2	6–12 months	$550
Coulter Odyssey 13	13.1	4.5	Cardboard	Dob	97	3	2	6–12 months	$800
Discovery 4.25 RFT/EQ	4.25	4	Aluminum	GEM	N/S	5	3	From stock	$330
Discovery 4.5 EQ	4.5	7.9	Aluminum	GEM	N/S	5	4	From stock	$400
Discovery 6 EQ	6	5	Aluminum	GEM	N/S	5	4	From stock	$500
Discovery 8 EQ	8	5	Aluminum	GEM	N/S	5	4	From stock	$600
Discovery 6 Dobsonian	6	8	Cardboard	Dob	N/S	5	3	From stock	$320
Discovery 8 Dobsonian	8	6	Cardboard	Dob	N/S	4	3	From stock	$420
Discovery 10 Dobsonian	10	4.5	Cardboard	Dob	N/S	3	2	From stock	$430
Discovery 17.5 Dobsonian	17.5	4.1	Cardboard	Dob	N/S	1	2	From stock	$1,750
Edmund 3	3	6	Plastic	Fork	12	5	3	From stock	$200
Edmund Astroscan	4.25	4	Plastic	Ball	13	5	4	From stock	$360
JMI NGT-12.5	12.5	4.5	Alum truss	Split-Ring Equatorial	120	2	4	2–8 weeks	$4,700
JMI NGT-18	18	4.5	Alum truss	Split-Ring Equatorial	245	2	3	4–8 weeks	$12,000
Mag One PortaBall 8	8	6	Alum truss	Ball	30	4	5	3–4 weeks	$1,200
Mag One PortaBall 12.5	12.5	5	Alum truss	Ball	67	3	4	8–10 weeks	$2,800
Meade 114NT/500	4.5	8	Aluminum	GEM	N/S	5	4	From stock*	$600
Meade 127NT/500	5	8	Aluminum	GEM	N/S	5	4	From stock*	$700

Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
Meade 4500	4.5	8	Aluminum	GEM	27	5	3	From stock*	$380
Meade Starfinder 6 Dob	6	8	Cardboard	Dob	34	5	3	From stock–2 months	$350
Meade Starfinder 8 Dob	8	6	Cardboard	Dob	44	5	3	From stock–2 months	$450
Meade Starfinder 10	10	4.5	Cardboard	Dob	62	4	3	From stock–2 months	$600
Meade Starfinder 12.5	12.5	4.8	Cardboard	Dob	96	3	3	2 months	$900
Meade Starfinder 16	16	4.5	Cardboard	Dob	170	2	3	3 months	$1,200
Meade Starfinder Equatorial 6	6	8	Cardboard	GEM	57	5	4	From stock–2 months	$650
Meade Starfinder Equatorial 8	8	6	Cardboard	GEM	69	4	4	From stock–2 months	$750
Meade Starfinder Equatorial 10	10	4.5	Cardboard	GEM	97	3	4	From stock–2 months	$880
Meade Starfinder Equatorial 16	16	4.5	Cardboard	GEM	247	2	3	3 months	$2,700
Obsession 15	15	4.5	Alum truss	Dob	88	3	4	2–3 months	$3,200
Obsession 18	18	4.5	Alum truss	Dob	109	3	3	2–3 months	$4,000
Obsession 20	20	5	Alum truss	Dob	141	2	2	2–3 months	$4,600
Obsession 25	25	5	Alum truss	Dob	240	1	2	2–3 months	$7,200
Obsession 30	30	4.5	Alum truss	Dob	395	1	1	2–3 months	$13,000
Orion Deep-Space Explorer 6	6	8	Cardboard	Dob	33	5	3	From stock–120 days	$360
Orion Deep-Space Explorer 8	8	6	Cardboard	Dob	41	5	3	From stock–120 days	$470
Orion Deep-Space Explorer 10	10	4.5	Cardboard	Dob	68	4	3	From stock–120 days	$700
Orion Premium DS Explorer 10	10	5.6	Cardboard	Dob	77	4	3	From stock–120 days	$800–$900 depends on focuser
Orion Premium DS Explorer 12.5	12.5	4.8	Cardboard	Dob	98	3	3	From stock–120 days	$1,030–$1,070 depends on focuser
Orion ShortTube 4.5 EQ	4.5	8.8	Aluminum	GEM	N/S	5	2	From stock	$250
Orion ShortTube 4.5 EQ Ultra	4.5	8.8	Aluminum	GEM	N/S	5	3	From stock	$400
Orion SkyView Deluxe 4.5	4.5	8	Aluminum	GEM	N/S	5	3	From stock	$460
Orion SkyView Deluxe 6	6	5	Aluminum	GEM	39	5	4	From stock	$600
Orion SpaceProbe3 Alt-az	3	9.2	Aluminum	Alt-az	8	5	2	From stock	$130
Orion SpaceProbe 3 EQ	3	9.2	Aluminum	GEM	17	5	2	From stock	$150
Orion SpaceProbe 4.5 EQ	4.5	7.9	Aluminum	GEM	N/S	5	3	From stock–2 months	$290
Orion/Vixen R200SS	7.9	4	Aluminum	GEM	N/S	5	4	From stock–2 months	$1,500
Parks Optical Companion Series	4.5	5	Fiberglass	SS	N/A	5	4	4 months	$800
Parks Optical Precision Series	6	6	Fiberglass	GEM	65	4	4	From stock	$950
Parks Optical Precision Series	6	8	Fiberglass	GEM	67	4	4	From stock	$950
Parks Optical Astrolight System	6	6 or 8	Fiberglass	GEM	42	4	4	From stock	$1,000
Parks Optical Astrolight Nitelight Series	6	3.5	Fiberglass	GEM	35	4	4	From stock	$1,300
Parks Optica H.I.T. Astrolight Series	6	4 (Newt) 12 (Cas)	Fiberglass	GEM	39	4	4	5 months	$2,500
Parks Optical H.I.T. Penta Series	6	4 or 12	Fiberglass	GEM	N/S	4	4	5 months	$5,000

Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
Parks Optical Precision Series	8	6	Fiberglass	GEM	85	3	4	From stock	$1,400
Parks Optical Superior Series	8	6	Fiberglass	GEM	185	2	5	From stock	$2,900
Parks Optical Astrolight Nitelight Series	8	3.5	Fiberglass	GEM	35	4	4	From stock	$1,300
Parks Optica Superior Nitelight Series	8	3.5	Fiberglass	GEM	169	1	5	From stock	$3,900
Parks Optical H.I.T. Astrolight Series	8	4 or 12	Fiberglass	GEM	73	3	5	5 months	$3,200
Parks Optical H.I.T. Penta Series	8	4 or 12	Fiberglass	GEM	N/S	3	5	5 months	$7,000
Parks Optical Superior Series	10	5	Fiberglass	GEM	205	1	5	From stock	$3,700
Parks Optical Superior Nitelight Series	10	3.5	Fiberglass	GEM	191	1	5	From stock	$4,400
Parks Optical H.I.T. Superior Series	10	4 or 12	Fiberglass	GEM	203	1	5	5 months	$6,000
Parks Optical Superior Series	12.5	5	Fiberglass	GEM	265	1	3	From stock	$4,600
Parks Optical Superior Nitelight Series	12.5	3.5	Fiberglass	GEM	231	1	5	From stock	$6,800
Parks Optical Observatory Series	12.5	5	Fiberglass	GEM	515	1	2	3 months	$14,000
Parks Optical H.I.T. Series	12.5	4 or 12	Fiberglass	GEM	249	1	4	5 months	$8,500
Parks Optical Observatory Nitelight Series	16	3.5	Fiberglass	GEM	615	1	4	From stock	$18,000
Parks Optical Observatory Series	16	5	Fiberglass	GEM	755	1	2	3 months	$16,400
Parks Optical H.I.T. Series	16	4 or 12	Fiberglass	GEM	655	1	4	5 months	$32,000
Sky Valley*** Rotating Tube 12.5	12.5	4 or greater	Alum truss	Dob	120	3	4	Varies	$3,350
Sky Valley*** Rotating Tube 14	14	4 or greater	Alum truss	Dob	130	3	4	Varies	$3,950
Sky Valley*** Rotating Tube 16	16	4 or greater	Alum truss	Dob	145	3	3	Varies	$4,500
Sky Valley*** Rotating Tube 18	18	4 or greater	Alum truss	Dob	160	3	3	Varies	$5,000
Sky Valley*** Ultra Light 12.5	12.5	4 or greater	Alum truss	Dob	60	3	4	Varies	$2,900
Sky Valley*** Ultra Light 14	14	4 or greater	Alum truss	Dob	75	3	4	Varies	$3,450
Sky Valley*** Ultra Light 16	16	4 or greater	Alum truss	Dob	100	3	3	Varies	$4,000
Sky Valley*** Ultra Light 18	18	4 or greater	Alum truss	Dob	115	3	3	Varies	$4,500
Sovietski (TAL-1M) 4.3	4.3	7.3	Aluminum	GEM	42	5	4	From stock	$450
Sovietski (TAL-2M) 6	6	8	Aluminum	GEM	88	4	5	From stock	$750
Stargazer Steve SGR-3	3	10	Cardboard	Alt-az	7	5	4	1 month	$230
Stargazer Steve 4.25 (kit)	4.25	10	Cardboard	Dob	16	5	4	From stock	$230
Stargazer Steve 6 (kit)	6	8	Cardboard	Dob	24	5	4	From stock	$380
StarMaster Large Aperture 12.5	12.5	5.2	Alum truss	Dob	95	3	5	90–120 days	$2,500
StarMaster Large Aperture 14.5	14.5	4.5	Alum truss	Dob	118	3	4	90–120 days	$3,000

Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
StarMaster Large Aperture 16	16	4.5	Alum truss	Dob	136	3	4	90–120 days	$3,400
StarMaster Large Aperture 18	18	4.5	Alum truss	Dob	158	2	3	90–120 days	$4,000
StarMaster Large Aperture 20	20	4.5	Alum truss	Dob	180	1	2	90–120 days	$4,800
StarMaster Large Aperture 22	22	4 or 4.5	Alum truss	Dob	205	1	2	90–120 days	$5,400 (f/4.5)
Starsplitter APO-Eater	6	10	Fiberboard	Dob	40	5	4	12–16 weeks	$1,000
Starsplitter APO-Eater	8	8	Fiberboard	Dob	45	4	4	12–16 weeks	$1,200
Starsplitter Compact 8	8	6	Two-pole	Dob	35	2	5	10–16 weeks	$1,000
Starsplitter Compact 10	10	6	Two-pole	Dob	40	2	4	10–16 weeks	$1,200–$1,500 DOM
Starsplitter Compact 12.5	12.5	4.8	Two-pole	Dob	57	2	3	10–16 weeks	$1,600–$1,900 DOM
Starsplitter Compact II 8	8	6	Alum truss	Dob	38	3	5	12–16 weeks	$1,300–$1,400 DOM
Starsplitter Compact II 10	10	6	Alum truss	Dob	50	3	5	12–16 weeks	$1,600–$1,800 DOM
Starsplitter Compact II 12.5	12.5	4.8 or 6	Alum truss	Dob	62	3	4	12–16 weeks	$1,900–$2,000 DOM
Starsplitter Compact II 14.5	14.5	4.5	Alum truss	Dob	72	3	3	12–16 weeks	$2,500–$2,700 DOM
Starsplitter Gem 4.5	4.5	8	Aluminum	GEM	28	5	4	From stock–30 days	$420
Starsplitter Gem 6	6	5	Aluminum	GEM	38	5	4	From stock–30 days	$575
Starsplitter Gem 6 Premium	6	5	Aluminum	GEM	38	5	4	From stock–30 days	$795
Starsplitter II 15	15	4.5	Alum truss	Dob	80	3	4	12–16 weeks	$3,000
Starsplitter II 16	16	4.7	Alum truss	Dob	90	3	4	12–16 weeks	$3,400–$3,900 DOM
Starsplitter II 18	18	4.5	Alum truss	Dob	102	3	3	12–16 weeks	$3,700–$4,300 DOM
Starsplitter II 20	20	5	Alum truss	Dob	136	2	2	12–16 weeks	$4,400–$4,800 DOM
Starsplitter II 25	25	5	Alum truss	Dob	240	1	1	12–16 weeks	$7,000–$8,800 DOM
Starsplitter II 30	30	4.5	Alum truss	Dob	375	1	1	12–16 weeks	$12,000–$12,200 DOM
Starsplitter II Light 20	20	4	Alum truss	Dob	124	2	2	14–16 weeks	$4,800–$5,400 DOM
Starsplitter II Light 22	22	4.5	Alum truss	Dob	145	2	2	14–16 weeks	$5,000–$6,300 DOM
Starsplitter II Light 24	24	4.5	Alum truss	Dob	160	2	1	14–16 weeks	$6,500–$6,600 DOM
Starsplitter II Light 28	28	4.5	Alum truss	Dob	244	1	1	14–16 weeks	$9,700–$10,000 DOM
Starsplitter Tube 6	6	8	Plastic coated cardboard tube	Dob	40	5	5	4–12 weeks	$500 (plate glass) $600 (Pyrex)
Starsplitter Tube 8	8	6	Plastic coated cardboard tube	Dob	45	4	5	4–12 weeks	$700 (plate glass) $800–$900 (Pyrex)
Starsplitter Tube 10	10	6	Plastic coated cardboard tube	Dob	70	3	5	4–12 weeks	$900 (plate glass) $1,000–$1,300 (Pyrex)
Starsplitter II Ultimate 30	30	4.5	Alum truss	Dob	375	1	1	30–52 weeks	$12,500
Starsplitter II Ultimate 32	32	4.3	Alum truss	Dob	375	1	1	30–52 weeks	$22,000
Starsplitter II Ultimate 36	36	4	Alum truss	Dob	375	1	1	30–52 weeks	$29,000
Starsplitter II Ultimate 40	40	4	Alum truss	Dob	N/S	1	1	30–52 weeks	$36,000
Takahashi CN-212	8.3	3.9 (Newt) 12.5 (Cas)	Aluminum	GEM	45	4	5	From stock–1 month	$6,200
Takahashi Epsilon 160	6.3	3.3	Aluminum	GEM	73	3	5	From stock–2 months	$7,100
Takahashi Epsilon 210	8.2	3	Aluminum	GEM	74	3	5	From stock–1 month	$15,250
Takahashi Epsilon 250	9.8	3.4	Aluminum	GEM	125	2	5	3–6 months	$16,000
Takahashi MT-130	5.2	6	Aluminum	SS	MD	5	4	1–3 months	$1,300
Takahashi MT-160	6.3	6	Aluminum	SS	MD	5	5	1–3 months	On request
Takahashi MT-200	7.9	6	Aluminum	SS	MD	4	5	1–3 months	On request

Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
Takahashi MT-250	9.8	6	Aluminum	SS	MD	3	4	1–3 months	On request
SCHMIDT-CASSEGRAIN TELESCOPES (SCTS)									
Celestron C-5 Spotting Scope	5	10	Aluminum	SS	6	5	2	From stock*	$600
Celestron C-5+	5	10	Aluminum	Single-arm Fork Eq	23	5	3	From stock*	$1,200
Celestron Celestar 8	8	10	Aluminum	Fork Eq	37	3	4	From stock*	$1,200
Celestron Celestar 8 Computerized	8	10	Aluminum	Fork Eq	37	3	4	From stock*	$1,700
Celestron Celestar 8 Deluxe	8	10	Aluminum	Fork Eq	40	4	5	From stock*	$1,800
Celestron Celestar 8 Deluxe Computerized	8	10	Aluminum	Fork Eq	40	4	5	From stock*	$2,300
Celestron CG 9-¼	9.25	10	Aluminum	GEM	53	3	4	From stock*–2 months	$2,400
Celestron CM-1100	11	10	Aluminum	GEM	105	2	4	From stock*–2 months	$3,400
Celestron CM-1400	14	10	Aluminum	GEM	135	1	3	From stock*–2 months	$5,800
Celestron G-5	5	10	Aluminum	GEM	17	5	4	From stock*	$800
Celestron G-8	8	10	Aluminum	GEM	45	4	4	From stock*	$1,000
Celestron Ultima 2000	8	10	Aluminum	Fork computer driven	32	4	4	From stock*	$2,800
Celestron Ultima 9-¼	9.25	10	Aluminum	Fork	74	3	4	From stock*–2 months	$2,500
Celestron Ultima 11	11	10	Aluminum	Fork	80	2	3	From stock*–2 months	$3,000
Meade 203SC/300	8	10	Aluminum	GEM	N/S	4	4	From stock–2 months	$800
Meade 203SC/500	8	10	Aluminum	GEM	N/S	4	4	From stock–2 months	$900
Meade LX10	8	10	Aluminum	Fork	49	4	4	From stock–2 months	$1,000
Meade LX10 Deluxe	8	10	Aluminum	Fork	49	4	5	From stock–2 months	$1,150
Meade LX50	8	10	Aluminum	Fork	71	4	4	From stock–2 months	$1,400
Meade LX50	10	10	Aluminum	Fork	89	3	4	From stock–2 months	$1,700
Meade LX200	8	6.3 or 10	Aluminum	Fork	69	4	4	From stock–2 months	$2,800
Meade LX200	10	6.3 or 10	Aluminum	Fork	86	3	5	From stock–2 months	$3,200
Meade LX200	12	10	Aluminum	Fork	120	2	3	2 months	$4,500
Meade LX200	16	10	Aluminum	Fork	313	1	3	3 months	$15,000
Orion/Vixen VC200L	7.9	9	Aluminum	GEM	N/S	4	4	From stock–120 days	$1,500
MAKSUTOV									
Celestron G-3 (Mak-Cass)	3.5	11	Aluminum	GEM	17	5	3	From stock*	$500
Intes MK67 (Mak-Cass)	6	12	Aluminum	SS	N/A	4	4	From stock*	$880
Intes MN56 (Mak-Newt)	5	6	Aluminum	SS	N/A	4	4	2 weeks	$800
Intes MN61 (Mak-Newt)	6	6	Aluminum	SS	N/A	4	5	From stock*	$1,240
Intes MN71 (Mak-Newt)	7	6	Aluminum	SS	N/A	4	5	4–6 weeks	$2,500
Intes MK66 (Mak-Cass)	6	12	Aluminum	SS	N/A	4	5	From stock*	$1,150
Intes MK69 (Mak-Cass)	6	6	Aluminum	SS	N/A	4	4	From stock*	$1,250
Intes MK91 (Mak-Cass)	9	13.5	Aluminum	SS	N/A	3	4	4–6 weeks	$3,000
Intes Micro Alter M603 (Mak-Cass)	6	10	Aluminum	SS	N/A	4	4	4–6 weeks	$1,240
Intes Micro Alter M703 (Mak-Cass)	7	10	Aluminum	SS	N/A	4	4	From stock*	$1,900

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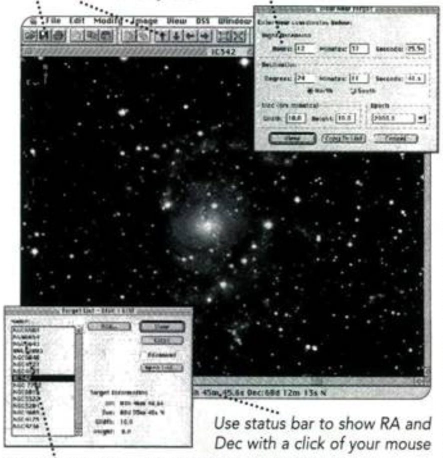

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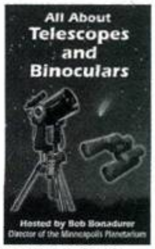

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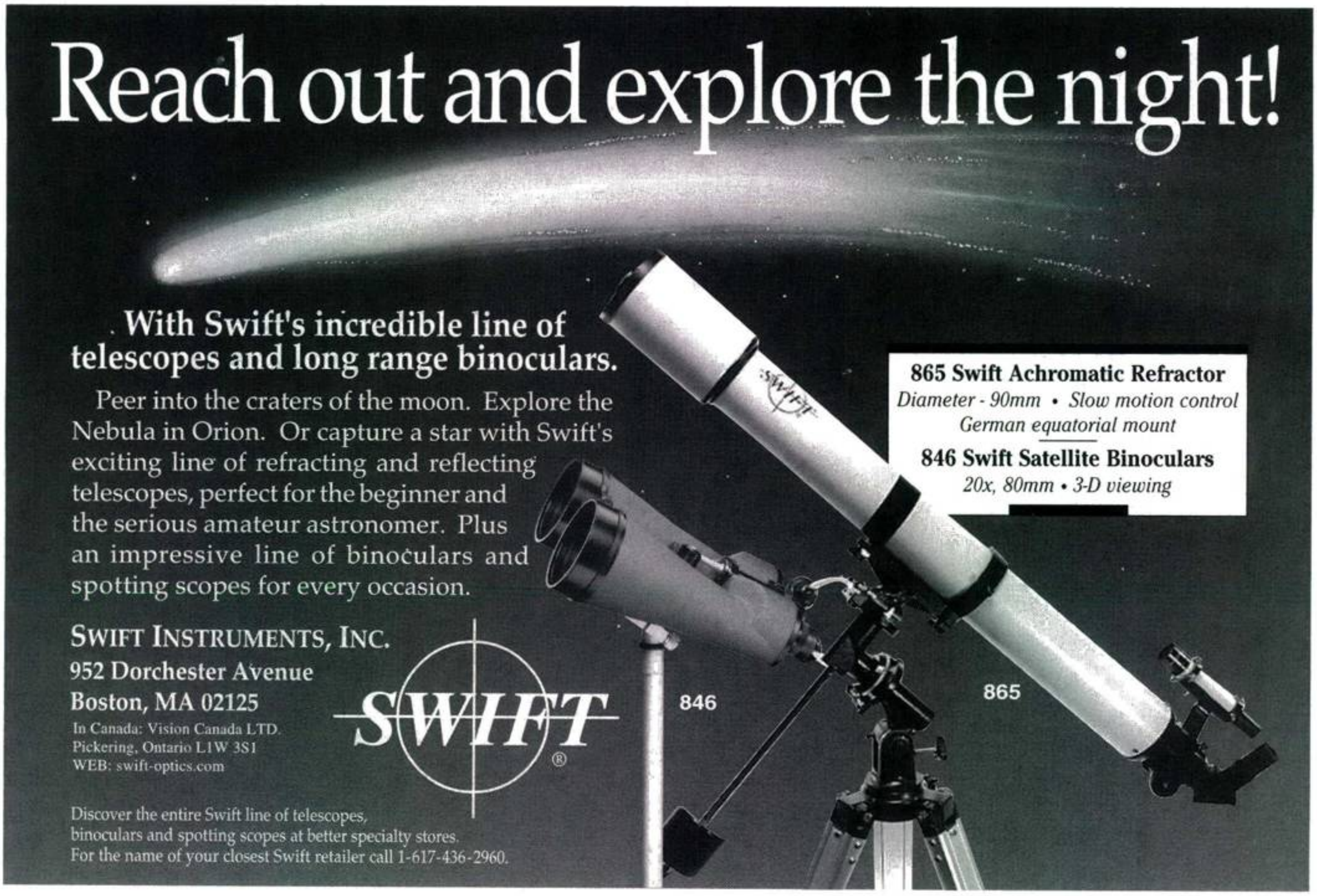

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Model	Aperture	Focal Ratio	Tube Material	Mount Type	Total Weight (lbs.)	Ease of Setup	Ease of Use	Typical Delivery	Price
Intes Micro Alter M809 (Mak-Cass)	8	10	Aluminum	SS	N/A	4	4	4–6 weeks	$3,800
Intes Micro Alter M1608 (Mak-Cass)	16	10–20	Aluminum	SS	N/A	2**	3	3–6 months	$20,000
Intes Micro MN86 (Mak-Newt)	8	6	Aluminum	SS	N/A	4	4	2–3 months	$4,000
Intes Micro Alter 1008 (Mak-Cass)	10	12.5	Aluminum	SS	N/A	3	4	2–3 months	$5,600
Intes Micro 12 (Mak-Cass)	12	10	Aluminum	SS	N/A	2	3	2–3 months	$12,900
Intes Micro 14 (Mak-Cass)	14	10	Aluminum	SS	N/A	2	3	2–3 months	$16,500
Luminon LOMO 150 (Mak-Cass)	6	13.3	Aluminum	GEM	N/A	4	4	From stock	$1,000
Meade ETX Spotting Scope (Mak-Cass)	3.5	13.8	Aluminum	SS	7	5	2	From stock*	$500
Meade ETX-EC (Mak-Cass)	3.5	13.8	Aluminum	Fork	9	5	1 (3 w/opt. computer drive)	From stock*	$600
Meade 7" LX50 (Mak-Cass)	7	15	Aluminum	Fork	82	4	4	From stock–2 months	$1,800
Meade 7" LX200 (Mak-Cass)	7	15	Aluminum	Fork	80	4	5	From stock–2 months	$3,300
Orion Argonaut 150 EQ (Mak-Cass)	6	12	Aluminum	GEM	34	5	4	From stock–1 month	$1,100
Orion Argonaut 6 GP-DX (Mak-Newt)	6	5.9	Aluminum	GEM	56	5	5	From stock–1 month	$2,000
Questar Standard 3.5 (Mak-Cass)	3.5	14	Aluminum	Fork	8	5	2	6–12 weeks	$4,000
Questar Duplex 3.5 (Mak-Cass)	3.5	14	Aluminum	Fork	8	5	2	6–12 weeks	$4,300

N/S: not specified; N/A: not applicable; CF: carbon fiber on request; SS: sold separately; MD: mount dependent; DOM: depends on optics manufacturer.

Ease Of Setup: Rated from 1 to 5, 5 being the best. Ease of use: Rated from 1 to 5, 5 being the best.

From Stock*: In cases where "From stock" is marked with an asterisk, delivery may depend on dealer's stock and the telescope may still take months to receive.

** In cases where "Ease of setup" is marked with a double asterisk, the telescope should be permanently mounted in an observatory.

*** NOTE: Sky Valley Scopes are custom-made instruments. Optics, focusers, and diagonal mirror assemblies are sold separately.

The weights and prices here reflect averages and may vary depending on equipment selected.

Delivery times are also averaged, and may be longer or shorter depending on availability of optics.

BINOCULARS

Model	Magnitude	Aperture	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (ounces)	Tripod Socket	Prism Type	Coatings	Typical Price
Bausch & Lomb Custom	8	36	6.5	C	4.5	19	22	Yes	BaK-4	MC	$270
Bausch & Lomb Custom	10	40	5.2	C	4	19	29	Yes	BaK-4	MC	$310
Bausch & Lomb Discoverer	7	42	8	C	6	20	29	No	BaK-4	MC	$320
Bausch & Lomb Discoverer	10	42	6.5	C	4.2	16	29	No	BaK-4	MC	$360
Bausch & Lomb Legacy	7	35	11	C	5	9	22	Yes	BaK-4	MC	$100
Bausch & Lomb Legacy	8	40	8.5	C	5	9	24	Yes	BaK-4	MC	$110
Bausch & Lomb Legacy	10	50	7.5	C	5	9	28	Yes	BaK-4	MC	$130
Brunton Eterna 7x42	7	42	9.3	C	6	22	28	Yes	BaK-4	FMC	$400
Brunton Eterna 8x40	8	40	8.3	C	5	20	28	Yes	BaK-4	FMC	$400
Brunton Eterna 10x50	10	50	6.5	C	5	21	33	Yes	BaK-4	FMC	$400
Bushnell Marine	7	50	7.0	I	7.1	N/S	37	No	BaK-4	FC	$210
Bushnell Natureview	8	42	8	C	5.3	19	26	Yes	BK-7	FC	$100
Bushnell Natureview	10	42	6	C	4.2	19	25	Yes	BK-7	FC	$120
Canon IS (Image Stabilizer)	10	30	6	C	3	15	21	No	Roof	MC	$600
Canon IS (Image Stabilizer)	12	36	5.6	C	3	15	31	No	Roof	MC	$950
Canon IS (Image Stabilizer)	15	45	4.5	C	3	15	36	No	Roof	MC	$1,400
Celestron Adventurer	7	50	6.4	C	7.1	17	31	Yes	BaK-4	MC	$140
Celestron Adventurer	10	50	5	C	5	16	31	Yes	BaK-4	MC	$140
Celestron Bird Watcher	7	35	10	C	5	14	20	Yes	BaK-4	MC	$90
Celestron Bird Watcher	8	40	9	C	5	14	21	Yes	BaK-4	MC	$100
Celestron Bird Watcher	10	50	6.5	C	5	13	26	Yes	BaK-4	MC	$110
Celestron Enduro	7	35	9.2	C	5	11	22	Yes	BK-7	FC	$40
Celestron Enduro	7	50	6.8	C	7.1	13	28	Yes	BK-7	FC	$50
Celestron Enduro	8	40	8.2	C	5	12	25	Yes	BK-7	FC	$40
Celestron Enduro	10	50	7	C	5	13	28	Yes	BK-7	FC	$50
Celestron Giant Deluxe	20	80	3.5	C	4	16	89	Yes	BaK-4	MC	$470
Celestron Giant Standard	20	80	3.5	C	4	14	74	Yes	BaK-4	MC	$370
Celestron Regal	8	42	6.3	C	5.3	20	24	Yes	BK-7	FMC	$370
Celestron Regal	10	50	5	C	5	20	28	Yes	BK-7	FMC	$400
Celestron Ultima	7	50	7	C	7.1	20	27	Yes	BaK-4	FMC	$240
Celestron Ultima	8	40	6.6	C	5	19	21	Yes	BaK-4	FMC	$200
Celestron Ultima	8	56	6.1	C	7	21	31	Yes	BaK-4	FMC	$290
Celestron Ultima	9	63	5.4	C	7	21	35	Yes	BaK-4	FMC	$350
Celestron Ultima	10	50	5	C	5	21	27	Yes	BaK-4	FMC	$250
Celestron Watersport	7	50	7	C	7.1	19	39	No	BaK-4	FC	$90
Celestron Watersport	10	50	6.5	C	5	19	40	No	BaK-4	FC	$100
Edmund	7	50	7	C	7.1	17	29	No	BK-7	FC	$70
Fujinon FMT-SX	7	50	7.5	I	7.1	23	50	Yes	BaK-4	FMC	$500
Fujinon FMT-SX	10	70	5.3	I	7	23	76	Yes	BaK-4	FMC	$600
Fujinon FMT-SX	16	70	4	I	4.4	12	76	Yes	BaK-4	FMC	$600
Fujinon 15x80MT-SX	15	80	4	I	5.3	16	256	Yes	BaK-4	FMC	$3,060
Fujinon 25x150MT-SX	25	150	2.7	I	6	19	656	Yes	BaK-4	FMC	$5,500
Fujinon 25x150ED-SX	25	150	2.7	I	6	19	656	Yes	BaK-4	FMC	$13,600

Model	Magnitude	Aperture	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (ounces)	Tripod Socket	Prism Type	Coatings	Typical Price
Fujinon 25x150EM-SX	25	150	2.7	I	6	19	688	Yes	BaK-4	FMC	$9,100
Fujinon 40x150ED-SX	40	150	1.7	I	3.8	15	656	Yes	BaK-4	FMC	$11,550
Fujinon MT-SX	7	50	7.5	I	7.1	12	45	Yes	BaK-4	FMC	$400
Fujinon MT-SX	10	70	5.3	I	7	12	76	Yes	BaK-4	FMC	$500
Fujinon MT-SX	16	70	4	I	4.4	12	76	Yes	BaK-4	FMC	$560
Kowa 7x40 ZCF	7	40	7.5	C	5.7	23	28	No	BaK-4	FMC	$150
Kowa 8x45 DCF	8	45	6.2	C	5.6	20	29	No	Roof	FMC	$260
Kowa 10x40 ZCF	10	40	6.3	C	4.2	17	28	No	BaK-4	FMC	$160
Kowa 10x45 DCF	10	45	6	C	4.5	12	30	No	Roof	FMC	$270
Leica Trinovid 7x42 BA	7	42	8.8	C	6	N/S	30	No	Roof	FMC	$950
Leica Trinovid 8x42 BA	8	42	8.2	C	5.3	N/S	30	No	Roof	FMC	$1,000
Leica Trinovid 10x42 BA	10	42	6.9	C	5	N/S	30	No	Roof	FMC	$1,050
Leica Trinovid 8x50 BA	8	50	7.2	C	6.5	N/S	38	No	Roof	FMC	$1,200
Leica Trinovid 10x50 BA	10	50	7.2	C	5	N/S	38	No	Roof	FMC	$1,250
Leica Trinovid 12x50 BA	12	50	6.3	C	4.2	N/S	40	No	Roof	FMC	$1,400
Leupold GR 10x40	10	40	5	C	4	17	29	No	Roof	FMC	$770
Leupold GR 12x50	12	50	4	C	4.2	17	37	No	Roof	FMC	$880
Meade Infinity 7x35WA	7	35	9.2	C	5	11	24	Yes	BK-7	FC	$60
Meade Infinity 8x40WA	8	40	8.2	C	5	11	26	Yes	BK-7	MC	$70
Meade Infinity 10x50WA	10	50	7	C	5	13	30	Yes	BK-7	FC	$70
Meade Mirage 7x35	7	35	8	C	5	14	21	No	BK-7	C	$40
Meade Mirage 10x50	10	50	5.7	C	5	13	25	No	BK-7	C	$50
Meade RainForest Pro 7x42WA	7	42	9.4	C	6	16	34	Yes	BaK-4 (roof)	MC	$430
Meade RainForest Pro 8x56	8	56	6.5	C	7	23	39	Yes	BaK-4 (roof)	MC	$450
Meade Safari Pro 7x36WA	7	36	9.3	C	5.1	19	24	Yes	BaK-4	MC	$150
Meade Safari Pro 8x42WA	8	42	8.2	C	5.3	19	26	Yes	BaK-4	MC	$160
Meade Safari Pro 10x42	10	42	6.1	C	4.2	16	24	Yes	BaK-4	MC	$170
Meade Safari Pro 10x50WA	10	50	6.5	C	5	16	32	Yes	BaK-4	MC	$180
Meade Travel View 7x35WA	7	35	9.2	C	5	12	23	No	BK-7	FC	$70
Meade Travel View 10x50WA	10	50	7	C	5	13	29	No	BK-7	FC	$90
Meade Travel View 12x50WA	12	50	5.4	C	4.2	13	30	No	BK-7	FC	$90
Minolta Activa 7x35W	7	35	9.3	C	5	19	24	Yes	BaK-4	FMC	$150
Minolta Activa 7x50	7	50	6.3	C	7.1	24	31	Yes	BaK-4	FMC	$170
Minolta Activa 8x40W	8	40	8.2	C	5	18	26	Yes	BaK-4	FMC	$160
Minolta Activa 10x50W	10	50	6.5	C	5	19	31	Yes	BaK-4	FMC	$180
Minolta Activa 12x50W	12	50	5.5	C	4.2	14	31	Yes	BaK-4	FMC	$190
Minolta Classic 7x35W	7	35	9.3	C	5	12	20	Yes	BK-7	C	$70
Minolta Classic 7x50	7	50	7	C	7.1	19	27	Yes	BK-7	C	$90
Minolta Classic 8x40W	8	40	8.2	C	5	12	23	Yes	BK-7	C	$70
Minolta Classic 10x50W	10	50	6.5	C	5	12	27	Yes	BK-7	C	$80
Miyauchi BS-77	20	77	2.5	I	3.9	20	106	Yes	BaK-4	FMC	$950
Miyauchi BJ100iA	20	100	2.5	I	5	27	208	Yes	BaK-4	FMC	$2,300
Miyauchi BJ100iA*	20	100	2.5	I	5	27	208	Yes	BaK-4	FMC	$2,900
Miyauchi BJ100iB*	20	100	2.5	I	5	27	208	Yes	BaK-4	FMC	$3,500

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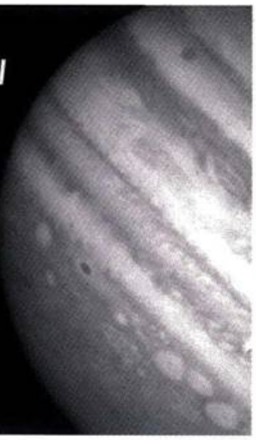

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Model	Magnitude	Aperture	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (ounces)	Tripod Socket	Prism Type	Coatings	Typical Price
Nikon Naturalist IV	7	35	9.3	C	5	12	23	Yes	BaK-4	MC	$100
Nikon Shoreline	7	50	6.4	C	7.1	20	32	Yes	BaK-4	MC	$140
Nikon Egret II	8	40	8.2	C	5	12	25	Yes	BaK-4	MC	$120
Nikon Lookout IV	10	50	6.5	C	5	20	32	Yes	BaK-4	MC	$140
Nikon Fieldmaster	12	50	5.5	C	4.2	9	32	Yes	BaK-4	MC	$160
Nikon 7x35E	7	35	7.3	C	5	16	20	**	BaK-4	MC	$350
Nikon 7x50 Sports and Marine	7	50	7.5	C	7.1	N/S	41	**	BaK-4	MC	$300
Nikon Superior E 10x42	10	42	6	C	4.2	17	24	**	BaK-4	FMC	$850
Nikon Superior E 12x50	12	50	5	C	4.2	17	30	**	BaK-4	FMC	$950
Nikon IF SP 7x50 (Prostars)	7	50	7.3	I	7.1	15	48	**	BaK-4	FMC	$850
Nikon IF SP 10x70 (Astroluxe)	10	70	5.1	I	7	15	70	**	BaK-4	FMC	$1,200
Nikon IF SP 18x70	18	70	4	I	3.9	15	68	**	BaK-4	FMC	$1,250
Nikon 20x120 III	20	120	3	I	6	21	544	Pedestal base sold separately	BaK-4	FMC	$6,000
Orion Giant	11	80	4.5	C	7	16	77	Yes	BaK-4	FMC	$400
Orion Giant	16	80	3.5	C	5	16	77	Yes	BaK-4	FMC	$400
Orion Giant	20	80	3.5	C	4	15	77	Yes	BaK-4	FMC	$400
Orion Little Giant II	11	70	4.5	C	6.4	18	47	Yes	BaK-4	FMC	$270
Orion Little Giant II	15	70	4	C	4.7	8	47	Yes	BaK-4	FMC	$270
Orion Little Giant II	20	70	3	C	3.5	8	47	Yes	BaK-4	FMC	$270
Orion Mini Giant	8	56	5.8	C	7	18	32	Yes	BaK-4	FMC	$160
Orion Mini Giant	9	63	5	C	7	18	36	Yes	BaK-4	FMC	$190
Orion Scenix	7	50	7.1	C	7.1	17	28	Yes	BK-7	FC	$90
Orion Scenix	8	40	9	C	5	14	24	Yes	BK-7	FC	$80
Orion Scenix	10	50	7	C	5	14	28	Yes	BK-7	FC	$90
Orion Supergiant	14	100	3.3	I	7	14	120	Yes	BaK-4	FMC	$1,250
Orion Supergiant	25	100	2.6	C	4	10	120	Yes	BaK-4	FMC	$1,250
Orion UltraView	7	50	6.5	C	7.1	22	32	Yes	BaK-4	FMC	$180
Orion UltraView	8	42	8.2	C	5.3	22	27	Yes	BaK-4	FMC	$160
Orion UltraView	10	50	6.5	C	5	22	32	Yes	BaK-4	FMC	$180
Orion Vista	7	50	6	C	7.1	22	28	Yes	BaK-4	FMC	$220
Orion Vista	8	42	6.5	C	5.25	18	22	Yes	BaK-4	FMC	$190
Orion Vista	10	50	5.3	C	5	16	28	Yes	BaK-4	FMC	$220
Orion/Vixen	20	125	3	I	6.2	20	384	Yes	BaK-4	MC	$3,650
Orion/Vixen	30	125	1.6	I	4.2	20	384	Yes	BaK-4	MC	$3,400
Orion/Vixen Binocular Telescope	36	80	1.1	I	2.2	N/S	176	Yes	BaK-4	MC	$880
Parks Optical GR	7	50	6.8	C	7.1	20	24	Yes	BaK-4	FMC	$170
Parks Optical TNE	7	50	6	C	7.1	25	27	Yes	BaK-4	FMC	$280
Parks Optical Waterproof Nitrogen filled	7	50	7	C	7.1	21	31	Yes	BaK-4	MC	$275
Parks Optical ZWCF	8	42	8.2	C	5.3	22	24	Yes	BaK-4	FMC	$170
Parks Optical DWCF	10	42	6.5	C	4.2	13	24	Yes	Roof	FMC	$270
Parks Optical ZWCF	10	52	6.5	C	5.2	22	28	Yes	BaK-4	FMC	$200
Parks Optical GR	10	50	5.3	C	5	18	25	Yes	BaK-4	FMC	$170
Parks Optical Deluxe Giant	10	70	5	C	7	20	60	Yes	BaK-4	FMC	$300

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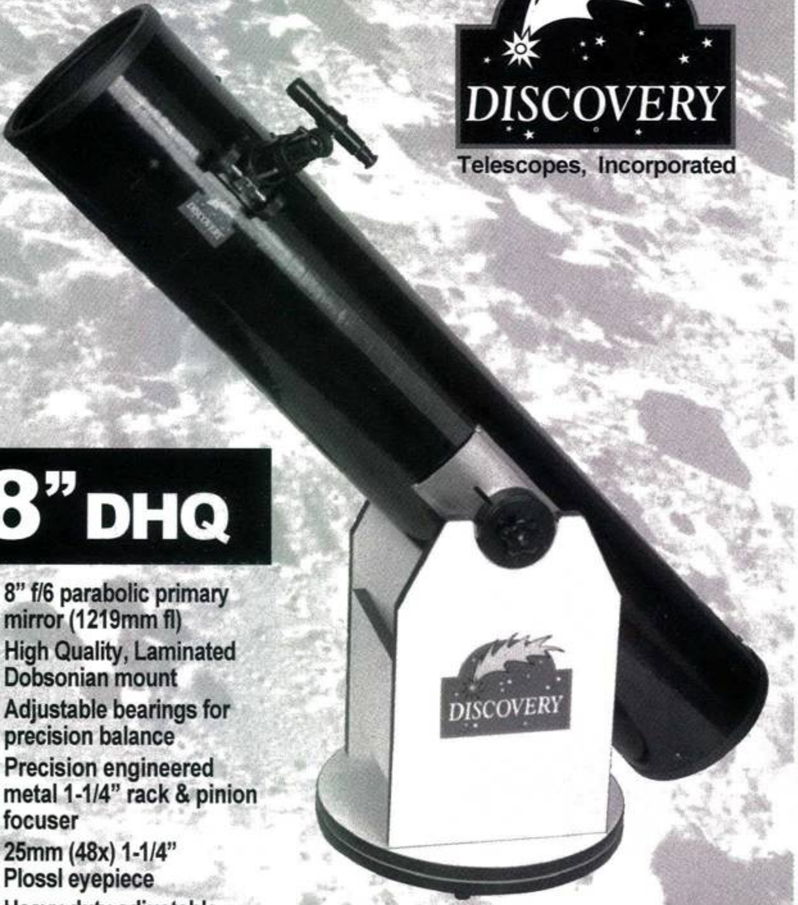

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Model	Magnitude	Aperture	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (ounces)	Tripod Socket	Prism Type	Coatings	Typical Price
Parks Optical Deluxe Giant	11	80	4.5	C	7.3	20	85	Yes	BaK-4	FMC	$400
Parks Optical GR	12	50	6	C	4.2	7	26	Yes	BK-7	FC	$140
Parks Optical Deluxe Giant	15	80	3.5	C	5.3	18	85	Yes	BaK-4	FMC	$440
Parks Optical Deluxe Giant	20	80	3.5	C	4	16	86	Yes	BaK-4	FMC	$490
Parks Optical Deluxe Giant	25	100	2.6	C	4	10	122	Yes	BaK-4	FMC	$1,900
Pentax PCF III	7	35	7.2	C	5	20	24	Yes	BaK-4	MC	$150
Pentax PCF III	7	50	6.2	C	7.1	20	34	Yes	BaK-4	MC	$170
Pentax PCF III	8	40	6.3	C	5	20	27	Yes	BaK-4	MC	$170
Pentax PCF III	10	50	5	C	5	20	34	Yes	BaK-4	MC	$180
Pentax PCF III	12	50	4.2	C	4.2	20	34	Yes	BaK-4	MC	$190
Pentax PCF III	16	50	3.1	C	4.2	20	35	Yes	BaK-4	MC	$200
Pentax PCF III	20	50	2.5	C	2.5	20	35	Yes	BaK-4	MC	$220
Pentax PIF	7	50	7.3	I	7.1	20	56	Yes	BaK-4	FMC	$700
Pentax PIF	10	50	6.5	I	5	15	56	Yes	BaK-4	FMC	$740
Sovietski 20x60	20	60	3.3	C	3	N/S	51	Yes	N/S	MC	$180
Sovietski 30x90	30	90	2	I	3	15	128	Yes	N/S	MC	$1,000
Sovietski 15x110	15	110	6	I	7.3	N/S	N/S	Yes	BaK-4	FMC	$2,750
Steiner 7x35 Military Marine	7	35	10	I	5	13	21	Yes	BaK-4	FMC	$350
Steiner 7x50 Military Marine	7	50	7	I	7.1	22	37	Yes	BaK-4	FMC	$470
Steiner 9x40 Big Horn	9	40	5.7	I	4.4	20	26	Yes	BaK-4	FMC	$380
Steiner 10x50 Military Marine	10	50	6.2	I	5	17	36	Yes	BaK-4	FMC	$470
Steiner 8x56 Hunting	8	56	6.6	I	7	21	41	Yes	BaK-4	FMC	$750
Steiner 9x40 Hunting	9	40	5.7	I	4.4	20	26	Yes	BaK-4	FMC	$500
Steiner 15x80 Senator	15	80	3.7	I	5.3	13	56	Yes	BaK-4	FMC	$1,000
Steiner 20x80 Senator	20	80	3.7	I	4	13	56	Yes	BaK-4	FMC	$1,000
Steiner Admiral-Gold 7x50	7	50	7.3	I	7.1	22	37	Yes	BaK-4	FMC	$770
Steiner Rallye 7x50	7	50	7.0	I	7.1	N/S	37	Yes	BaK-4	MC	$400
Steiner Rallye 10x50	10	50	6.2	I	7.1	N/S	36	Yes	BaK-4	MC	$400
Swarovski Habicht 7x42	7	42	6.4	C	6	14	24	Yes	BaK-4	MC	$530
Swarovski Habicht 7x42GA	7	42	6.4	C	6	14	27	Yes	BaK-4	MC	$660
Swarovski Habicht 10x40W	10	40	6.2	C	4	13	24	No	BaK-4	MC	$600
Swarovski Habicht 10x40W GA	10	40	6.2	C	4	13	28	No	BaK-4	MC	$730
Swarovski SL 7x50B	7	50	7.2	C	7.1	13	38	Yes	BaK-4	MC	$920
Swarovski SL 8x56B	8	56	5.8	C	7	13	44	Yes	BaK-4	MC	$1,050
Swarovski SL 10x50B	10	50	5.8	C	5	8	36	Yes	BaK-4	MC	$920
Swarovski SLC 7x42B	7	42	8	C	6	19	34	Yes	Roof	MC	$970
Swarovski SLC 7x50B	7	50	7.1	C	7.1	23	41	Yes	Roof	MC	$1,150
Swarovski SLC 8x50B	8	50	7	C	6.3	21	41	Yes	Roof	MC	$1,150
Swarovski SLC 8x56B	8	56	6.6	C	7	22	47	Yes	Roof	MC	$1,350
Swarovski SLC 10x42B	10	42	N/S	C	N/S	N/S	31	Yes	Roof	MC	$1,000
Swarovski SLC 10x50B	10	50	6.4	C	5	17	42	Yes	Roof	MC	$1,250
Swift Aerolite 7x35W	7	35	9.5	C	5	8.5	24	No	BK-7	FC	$60
Swift Aerolite 7x50	7	50	7.1	C	7.1	14	39	No	BK-7	FC	$70
Swift Aerolite Birder 8x40	8	40	9	C	5	16	33	No	BK-7	FC	$60

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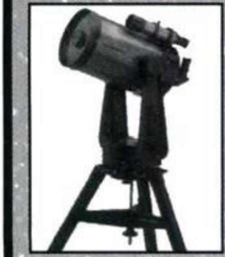

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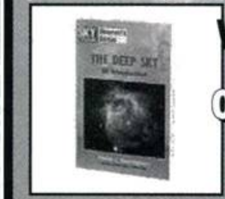

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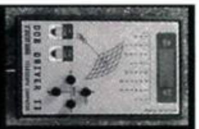

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Model	Magnitude	Aperture	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (ounces)	Tripod Socket	Prism Type	Coatings	Typical Price
Swift Aerolite 10x50	**10**	**50**	**5.2**	**C**	**5**	**13**	**37**	**No**	**BK-7**	**FC**	**$70**
Swift Audubon	8.5	44	8.2	C	5.2	9	29	Yes	BaK-4	MC	$270
Swift Audubon ED	**8.5**	**44**	**8.2**	**C**	**5.2**	**14.5**	**29**	**Yes**	**BaK-4**	**FMC**	**$550**
Swift Cougar	10	50	7	C	5	13	29	Yes	BaK-4	FC	$120
Swift Kestrel	**10**	**50**	**7**	**C**	**5**	**15**	**29**	**Yes**	**BaK-4**	**MC**	**$300**
Swift Observer	11	80	4.5	C	7.3	16	78	Yes	BaK-4	MC	$400
Swift Plover	**8**	**40**	**9**	**C**	**5**	**14**	**25**	**Yes**	**BaK-4**	**FC**	**$100**
Swift Satellite	20	80	3.5	C	4	15	80	Yes	BaK-4	MC	$430
Swift Sea Hawk	**7**	**50**	**7.5**	**I**	**7.1**	**19**	**42**	**Yes**	**BaK-4**	**FC**	**$270**
Swift Sea Wolf	10	50	7.1	C	5	19	33	Yes	BK-7	FC	$240
Swift Ultra Lite	**7**	**42**	**7**	**C**	**6**	**25**	**21**	**Yes**	**BaK-4**	**MC**	**$240**
Swift Ultra Lite	8	42	6.6	C	5.3	22	21	Yes	BaK-4	MC	$260
Swift Ultra Lite	**10**	**42**	**6.6**	**C**	**4.2**	**13**	**21**	**Yes**	**BaK-4**	**MC**	**$270**
Swift Vanguard	15	60	4.2	C	4	10	40	Yes	BK-7	MC	$240
Tasco Rare Bird 7x42	**7**	**42**	**7.6**	**C**	**6**	**18**	**26**	**Yes**	**BaK-4**	**FMC**	**$100**
Tasco Rare Bird 8x42	8	42	6.6	C	5.3	16	28	No	Roof	FMC	$300
Tasco Rare Bird 10x42	**10**	**42**	**6.5**	**C**	**4.2**	**16**	**27**	**Yes**	**BaK-4**	**FMC**	**$150**
Unitron High Eyepoint 7x50	7	50	6.8	C	7.1	N/S	26	Yes	BaK-4	FMC	$230
Unitron High Eyepoint 10x50	**10**	**50**	**5.3**	**C**	**5**	**N/S**	**27**	**Yes**	**BaK-4**	**FMC**	**$240**
Unitron Long Range 11x80	11	80	4.5	C	7.3	N/S	56	Yes	BaK-4	FMC	$330
Unitron Long Range 20x80	**20**	**80**	**2.7**	**C**	**4**	**N/S**	**56**	**Yes**	**BaK-4**	**FMC**	**$340**
Unitron Long Range 25x100	25	100	2.6	C	4	N/S	136	Yes	BaK-4	FMC	$1,200
Zeiss 7x42 B/GA T Classic*	**7**	**42**	**9.4**	**C**	**6**	**19**	**28**	**No**	**Roof**	**FMC**	**$950**
Zeiss 7x45 B T DesignSelection*	7	45	9.5	C	6.4	18	41	No	Roof	FMC	$1,200
Zeiss 10x40 B/GA T Classic*	**10**	**40**	**6.9**	**C**	**4**	**16**	**27**	**No**	**Roof**	**FMC**	**$970**
Zeiss 7x50 B/GA T Classic*	7	50	8.2	C	7.1	18	41	No	BaK-4	FMC	$1,400
Zeiss 8x56 B/GA T Classic*	**8**	**56**	**6.9**	**C**	**7**	**19**	**36**	**No**	**Roof**	**FMC**	**$1,200**
Zeiss 8x56 B T DesignSelection*	8	56	8.3	C	7	17	51	No	Roof	FMC	$1,400
Zeiss 10x56 B T DesignSelection*	**10**	**56**	**6.9**	**C**	**5.6**	**16**	**50**	**No**	**Roof**	**FMC**	**$1,500**
Zeiss 20x60 S	20	60	3.1	C	3	14	57	Yes	BaK-4	FMC	$4,600

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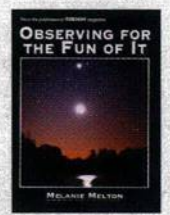

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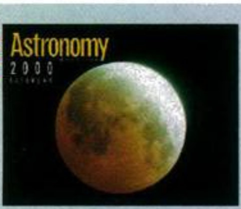

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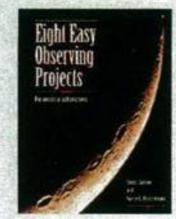

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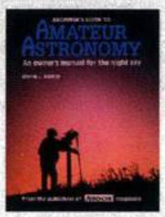

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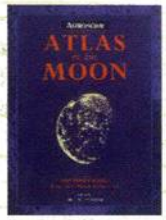

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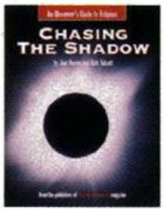

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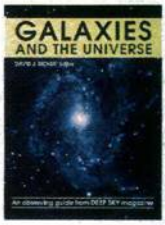

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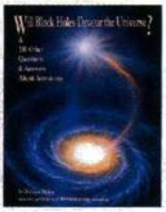

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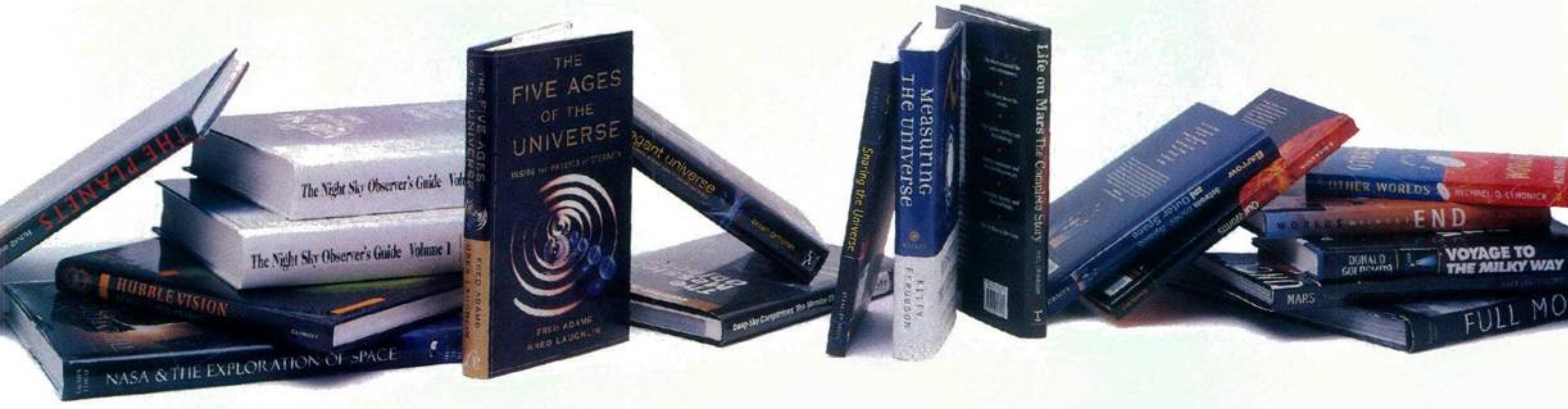
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Looking for a good read that will take you to the edge of the cosmos? Search no further.

by David J. Eicher

Just as nervous TV execs line up a whole new slate of sitcoms to dazzle viewers each season, book publishers produce more than 10,000 new titles every year, hoping that some will be hits. Astronomy gets its share of the spotlight, and each year from now on *Explore the Universe* will bring you a summary of the best recent astronomy titles. So sit back, relax, and get ready to pull out the VISA card and head to Barnes & Noble. . . .

So many of us who have nurtured a love of observing the cosmos over the past generation owe our interest in part to Carl Sagan's popularization of astronomy in the 1970s and 80s. We feel this despite academia's occasional sharp stings at the now-departed scientist for communicating like an ordinary mortal. Those who want to relive the halcyon days of *Cosmos* might pick up one of two recent books on the Cornell professor. For a chatty, unforgiving tell-all narrative that centers mostly on Sagan's personality and personal life, try Keay Davidson's *Carl Sagan: A Life* (★★★, 481 pp., Wiley, New York, 1999, $30). Stories of Sagan's adventures promoting planetary missions, having an affair, smoking pot, and chaotically producing his television masterpiece may startle as well as delight purists. A more definitive and balanced portrait containing superb scientific discussions emerges from *Carl Sagan: A Life in the Cosmos* by William Poundstone (★★★★, 449 pp., Henry Holt, New York, 1999, $30). Poundstone's product is more finely crafted, with a subtle, studied analysis of the subject woven throughout.

Sagan wanted to lead us all up to the window of his spaceship, provide a vision of the beginning or fate of the universe, and have it all be understood. Current books aim for this too, among them *The Five Ages of the Universe* by Fred Adams and Greg Laughlin (★★★½, 251 pp., Free Press, New York, 1999, $25).This ambitious work attempts to summarize five basic eras spanning the whole of the universe's existence, reliving its Big Bang formation through to the present and looking ahead to the Dark Era, at age 10^{100} years, when the universe will be a sad, lonely, dead place indeed. Alternately strange and enthralling, Brian Greene's *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (★★★½, 448 pp., W. W. Norton, New York, 1999, $27.95) summarizes the movement of physics toward a theory of everything. Greene, a professor of physics at Cornell, elegantly covers vast territory and soothes the complexity of string theory with simple diagrams. The scientific and human story of an area that has produced such notions as black holes transmuting into ordinary particles, rifts in the space-time continuum, and multiple universes receives careful scrutiny in this work. A more down-to-earth spin on the cosmos comes from Kitty Ferguson's *Measuring the Universe: Our Historic Quest to Chart the Horizons of Space and Time* (★★★½, 272 pp., Walker and Co., New York, 1999, $27). This historical tale follows the struggles of Copernicus, Cassini, Newton, Herschel, *Hubble*, and Leavitt, those who labored to unravel and explain the scale of things — the firmament, the stars, the galaxy, other galaxies. Engagingly composed,

Photo by William Zuback

this work belies the claim that historical writing can't become a riveting page-turner.

If the universe's distance scale overwhelms, grapple something more ethereal with Henning Genz's *Nothingness: The Science of Empty Space* (★★★, 340 pp., Helix Books/ Perseus Books, Reading, Mass., 1998, $30). Professor Genz's workmanlike treatment of this unusual topic covers a broad expanse of odd subjects, spinning all together in the quest to understand what kind of a vacuum space can be. Indeed, on average, each atom in intergalactic space floats about one meter apart. Yet the space between shines with light and other forms of radiation. The work gingerly walks through explorations in physics and history in search of answers.

More advanced explorations of cosmological topics appear in John D. Barrow's *Between Inner Space and Outer Space* (★★★, 274 pp., Oxford University Press, New York, 1999, $30). An anthology of articles that have appeared mostly in British papers, the book touches philosophy as it considers simplicity vs. complexity in the cosmos, theories of everything, extraterrestrial life, and the evolving relationship between science and religion. Barrow masterfully constructs relationships out of apparently diverse subjects; the lack of relation from essay to essay will not prevent enjoying the author's gem passages. Another compilation of essays, *Seven Wonders of the Cosmos* by Jayant V. Narlikar (★★½, 324 pp., Cambridge University Press, New York, 1999, cloth $59.95, paper $19.95) will also delight, but only a more technical crowd. The wonders, offered up with diagrams and photographs of discoverers, include pulsars, supernovae, stellar giants and dwarfs, and gravity.

Stepping back into the solar system from deep space brings readers a quintet of thoughtful essays. Attacking a recurring "news" story head-on, Paul Chambers brings us *Life on Mars: The Complete Story* (★★, 222 pp., Blandford, London, 1999, $22.95). Whereas this work can't deliver the complete story on a topic that's as yet unresolved, the book delivers a well-written description of the various missions to Mars, concentrating on Pathfinder and the much ballyhooed story of meteorite ALH84001. A final

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section contains summaries of alleged contact with "martians," whether it be "psychically," via UFOs, or by simply observing their "monuments" on the planet's surface. Thereafter, the book peters out, a victim of taking on a story without a conclusion.

Greater variety emerges from *Worlds Without End* by John S. Lewis (★★★½, 236 pp., Helix Books/Perseus Books, Reading, Mass., 1998, $24). Lewis, a planetary scientist at the University of Arizona, has delivered a highly readable and entertaining narrative about solar system research, an overview of the gassy and rocky worlds orbiting the sun, and the current status of searches for planets orbiting other stars. It's a great deal of ground to cover in 222 pages, but Lewis does it with skill and insight. Readers of the work will receive a clear understanding of how planetary scientists have arrived at understanding what they do. In Lewis's book the focus squarely strikes the science; another recent work highlights the human story of planetary science. *Our Worlds: The Magnetism and Thrill of Planetary Exploration*, edited by S. Alan Stern (★★★½, 172 pp., Cambridge University Press, New York, 1999, cloth $54.95, paper $19.95) presents the life stories of nine planetary scientists — Ellen Stofan, Clark Chapman, and John Spencer among them — their research, their lives, and how they got involved in what they're doing. In some ways the work is far more valuable than a scientific tome covering the same ground because it deeply underscores that science is a human process.

William E. Burrows gives us a solid, detailed chronicle of space exploration in *This New Ocean: A History of the First Space Age* (★★★, 285 pp., Random House, New York, 1998, $34.95). Exhaustively researched and employing now-declassified U.S. and Russian documents, the book describes the incompetent, uncoordinated initial efforts of the Soviet Union to beat America to the moon. It explores NASA's relationship with the military and the fallout Apollo left on NASA's following decades. To look ahead rather than behind, consult Donald Goldsmith's *Voyage to the Milky Way: The Future of Space Exploration* (★★½, 255 pp., TV Books, New York, 1999, $27.50). Tied in to the PBS series, this work offers a view of futuristic space travel that is sometimes plausible and at times highly speculative. Still, it offers curious reading and will be greatly enjoyed by true believers.

Coffee-table browsers have an impressive array of books to contemplate this year. The most spectacular of these is *Full Moon* by Michael Light, with an essay by Andrew Chaikin (★★★★, 129 plates and five gatefold panoramas, Alfred A. Knopf, New York, 1999, $50). Published on the 30th anniversary of the Apollo 11 landing, this book simply must be seen to be appreciated. The choices of photographs for inclusion in this rich, illustrated work are superb — many depict unfamiliar scenes in striking detail and some are previously unpublished. The reproduction quality is stunning, and the book's oversized square format results in a lunar treasure.

Also certain to make a splash with globe watchers, *The Planets* by David McNab and James Younger (★★★½, 240 pp., Yale University Press, New Haven, Conn., 1999, $35) accompanies last autumn's documentary series for the A&E cable network. The design, reproduction quality, writing, and spirit of adventure in this book are all first-rate. Either as a keepsake for viewers of the television series or as a spirited introduction to the solar system, this work will find many satisfied readers.

Richly illustrated and luxuriously produced, fans of the Red Planet will have to own *Mars: Uncovering the Secrets of the Red Planet* by Paul Raeburn (★★★★, 231 pp., National Geographic Society, Washington, 1998, $40). With commentary by Mars Pathfinder Project Scientist Matt Golombek and a catchily written text, this work will delight readers who have followed all the Mars exploration activity of the past several years. The real bang comes from the splendid array of dozens of images, which reflects the newsy style of National Geographic magazine. Many 3-D Mars Pathfinder images are included, as are two pairs of glasses to view them. What's not to like?

Rather than casting its eye on the planets, *NASA & the Exploration of Space* by Roger D. Launius and Bertram Ulrich (★★★, 224 pp., Stewart, Tabori, and Chang, New York, 1998, $60) presents more than 200 works of art from NASA's archive and the National Air and Space Museum. The work contains its share of truly odd conceptual art, as with James Cunningham's "Chaos and

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Order," revealing a peculiar geometric surface of Miranda with Uranus in the background.

Hubble Vision: Further Adventures with the Hubble Space Telescope by Carolyn Collins Petersen and John C. Brandt (★★★★, 2d edition, 224 pp., Cambridge University Press, New York, 1998, $39.95) contains a version of the story of Hubble updated from the 1995 first edition. A rich trove of images with explanatory text highlights some of Hubble's greatest hits. The well-crafted narrative challenges readers to comprehend a wide variety of subjects studied with Hubble. The only downside of this impressive tome is that in an era when new Hubble images are streaming down for release nearly every week, it's difficult to stay "current" in book form. Though it carries a relatively slim size and hefty price, *The Invisible Universe* by David Malin (★★★, 132 pp., Little, Brown, and Co., New York, 1999, $50) will please fans of the legendary imager of the Southern sky. All the classic Malin shots are here, including the Horsehead Nebula, Orion Nebula, Helix Nebula, barred spiral M83, and many others. Similarly, *Other Worlds: The Solar System and Beyond* by James Trefil (★★★⯪, 240 pp., National Geographic Society, Washington, 1999, $35) presents 175 color images of the cosmos with accompanying commentary from the accomplished science writer. The all-encompassing tour takes readers through the whole of the universe in space and time, exploring the planets, the Milky Way, and other galaxies. It also considers the early and future days of the universe.

Other books consider the possibilities of extraterrestrial life. Michael D. Lemonick's outstanding *Other Worlds: The Search for Life in the Universe* (★★★★, 272 pp., Simon & Schuster, New York, 1998, cloth $25, paper $14) offers a smoothly written narrative of the many pathways by which scientists are searching for other life. A story of the science and the characters involved, Lemonick's narrative transports readers to Mauna Kea, Green Bank, the Mirror Lab at the University of Arizona, the SETI Institute in California, and NASA's hallways for discussions of the martian meteorite. It's a winner. A more personal, and technical, overview of the SETI portion emerges from *Sharing the Universe: Perspectives on Extraterrestrial Life* by Seth Shostak (★★★, 206 pp., Berkeley Hills Books, Berkeley, Calif., 1998, $14.95). Written by the public programs scientist of the SETI Institute, the work offers an impassioned insider's view of the search. Philosophical reflections on the possible array of other living beings are inspired and rational, revealing how complex and wildly different other life might be and how silly and human-centric Hollywood's depictions of it have been to date.

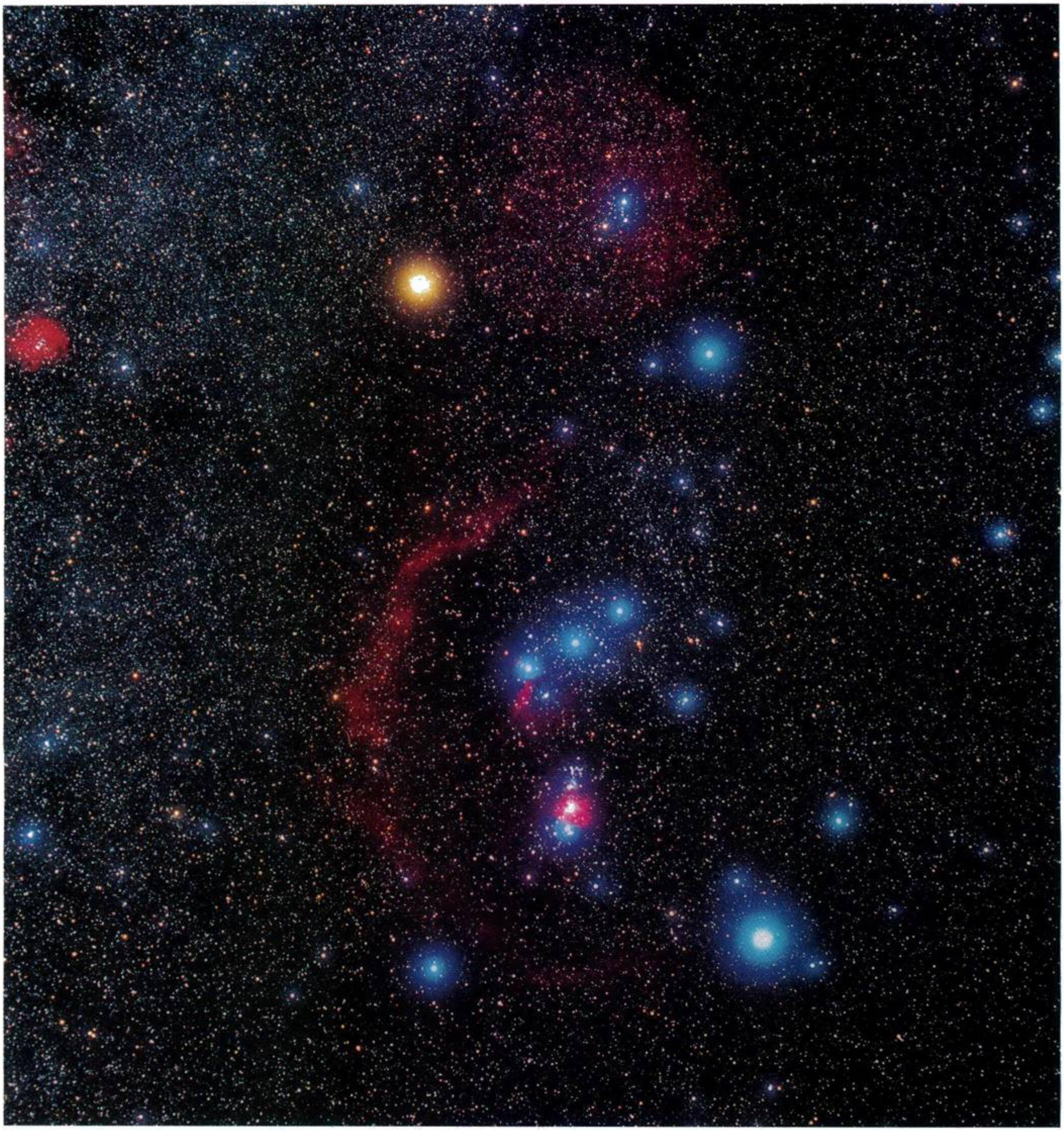
Of course there's the other side of the astronomical coin — the books for backyard hobbyists. They offer critical how-to information for observers and tinkerers. This year's cache of best books slants heavily toward observers. For sheer volume of information, it's hard to beat *The Night Sky Observer's Guide* by George Robert Kepple and Glen W. Sanner (★★★, two vols., 936 pp., Willmann-Bell, Richmond, Va., 1998, $69.90). A republished compilation of telescopic observations from the magazine *The Observer's Sky*, the book is akin to *Burnham's Celestial Handbook* by virtue of offering numerous current observational comments on galaxies, clusters, and nebulae with a wide variety of telescopes. A scattering of maps, tables, photos, and sketches complements the text. The quality of information varies with the observer in Kepple and Sanner's book. A more uniform standard resides in Stephen James O'Meara's *Deep Sky Companions: The Messier Objects* (★★★⯪, 304 pp., Cambridge University Press and Sky Publishing Corp., New York, 1998, $34.95). This impressive work supplants *The Messier Album*, an earlier and well-read Messier book by John Mallas and Evered Kreimer, and contains careful descriptions of each object, finder maps, telescopic drawings, and photographs. The text is spirited and informed, and the result is a must-have on the bookshelf of deep-sky enthusiasts.

Have a favorite astronomical book that's recently appeared? Send us a comment on why we should include it next year in *Explore the Universe 2001*. In the mean time, enjoy the skies and the intellectual journeys to other worlds past and present.

David J. Eicher is editor of Explore the Universe 2000.

The Beautiful Universe

A gallery of some of the best photographs from the readers of Astronomy.



Magnificent Orion

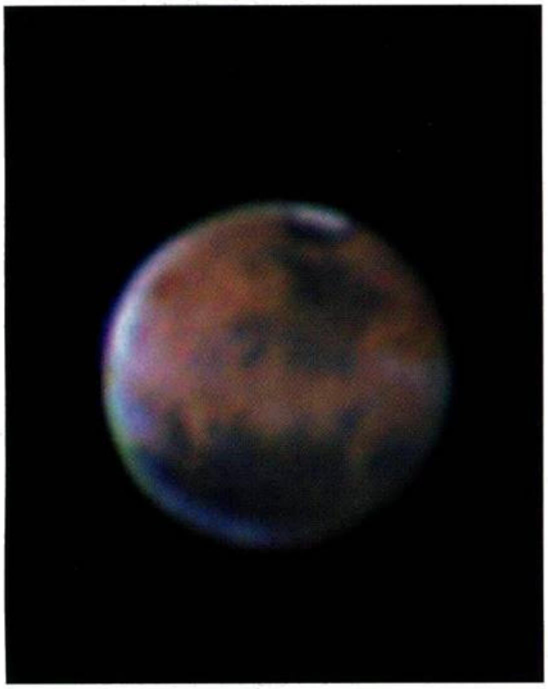
BILL AND SALLY FLETCHER

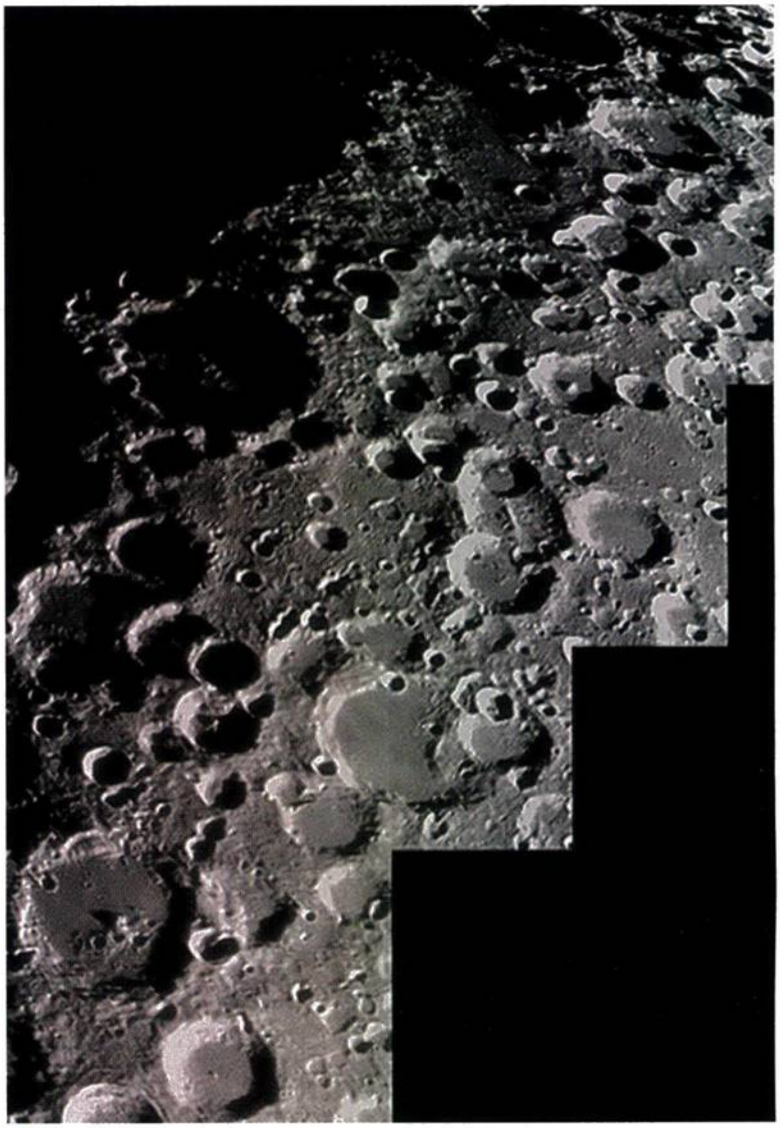
Rigel and Betelgeuse show their true colors beside Orion's elusive gas clouds.
(90mm lens, Kodak Pro 400 PPF film, 60-minute exposure)

Mighty Mars

MAURIZIO DI SCIULLO

Spring 1999 had Mars at opposition and Red Planet observers busy at their cameras. (10-inch reflector at f/48, CCD camera, taken April 6, 1999)

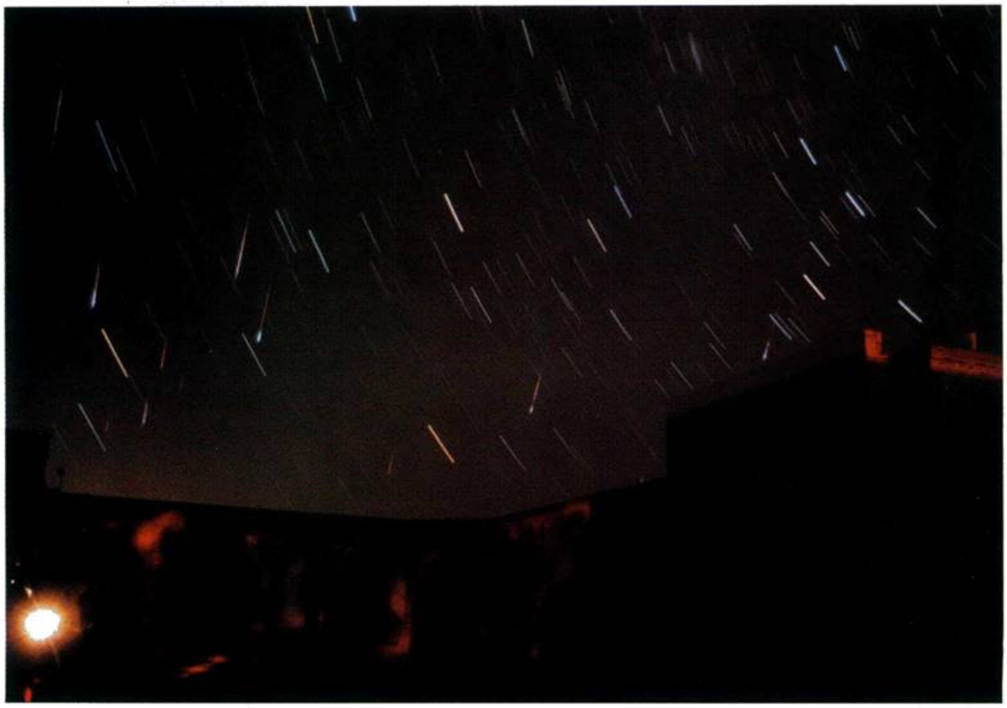




Moon Mosaic

GIORGIO MENGOLI

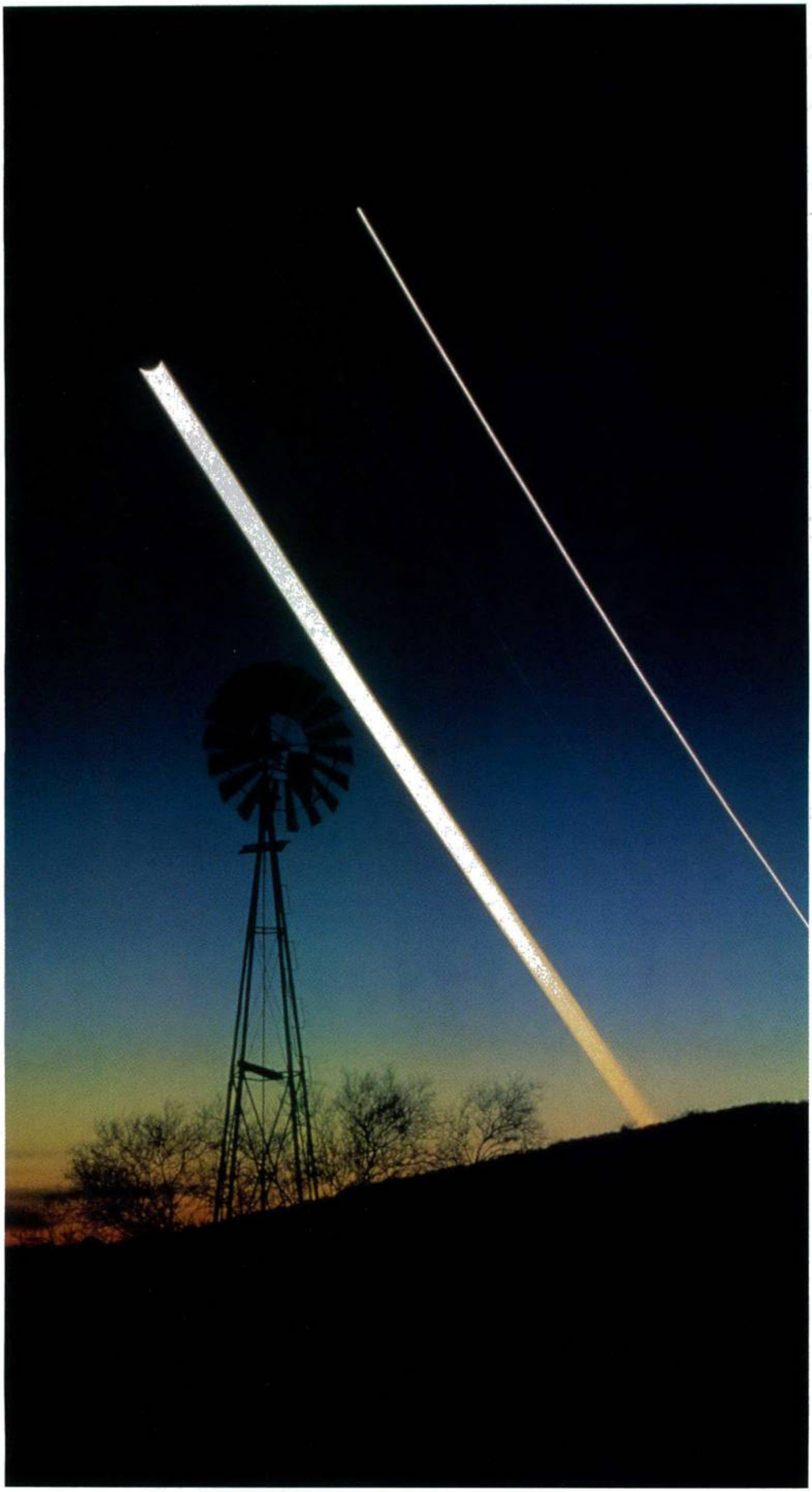
The thirtieth anniversary of the first landing on the moon by Apollo astronauts was celebrated in July 1999. (6-inch f/9 apochromatic refractor, CCD camera, taken April 23, 1999)



Leonid Count

OSHIN D. ZAKARIAN

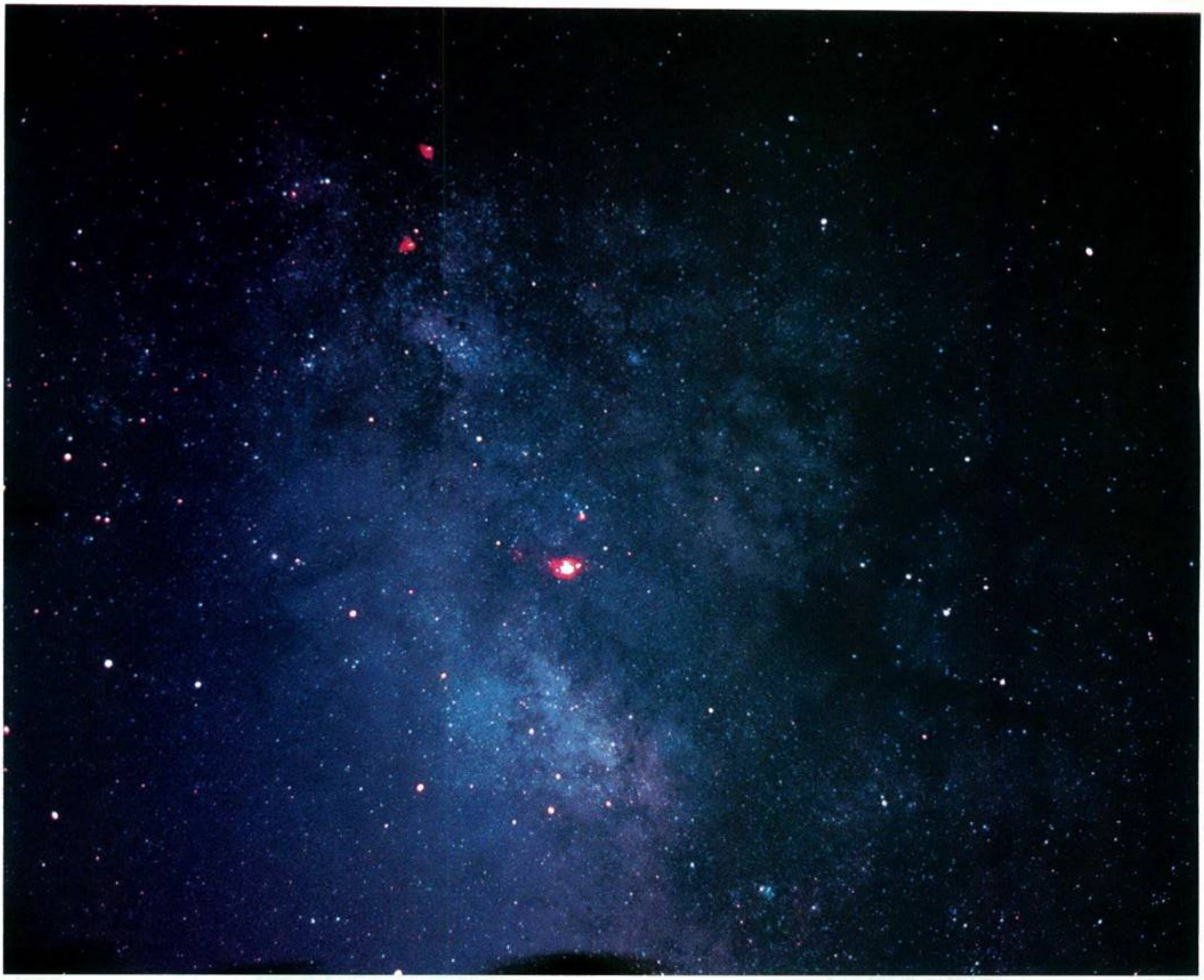
Can you find all fourteen Leonid meteors in this photo? (35mm lens at f/2.8, Fuji Super G 800+ film, 20-minute exposure taken November 17, 1998)

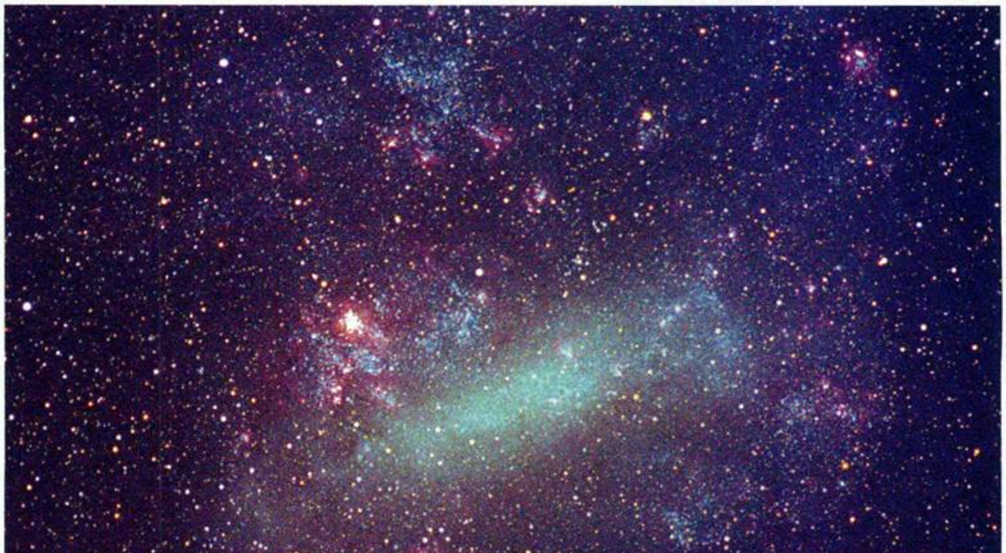


Windmill Star Trails

DAVID LINNIG

The moon, Saturn, and Venus set behind this windmill near Lordsburg, New Mexico.
(180mm lens at f/16, Fujichrome Velvia film, 90-minute exposure taken March 19, 1999)





Milky Way Panorama

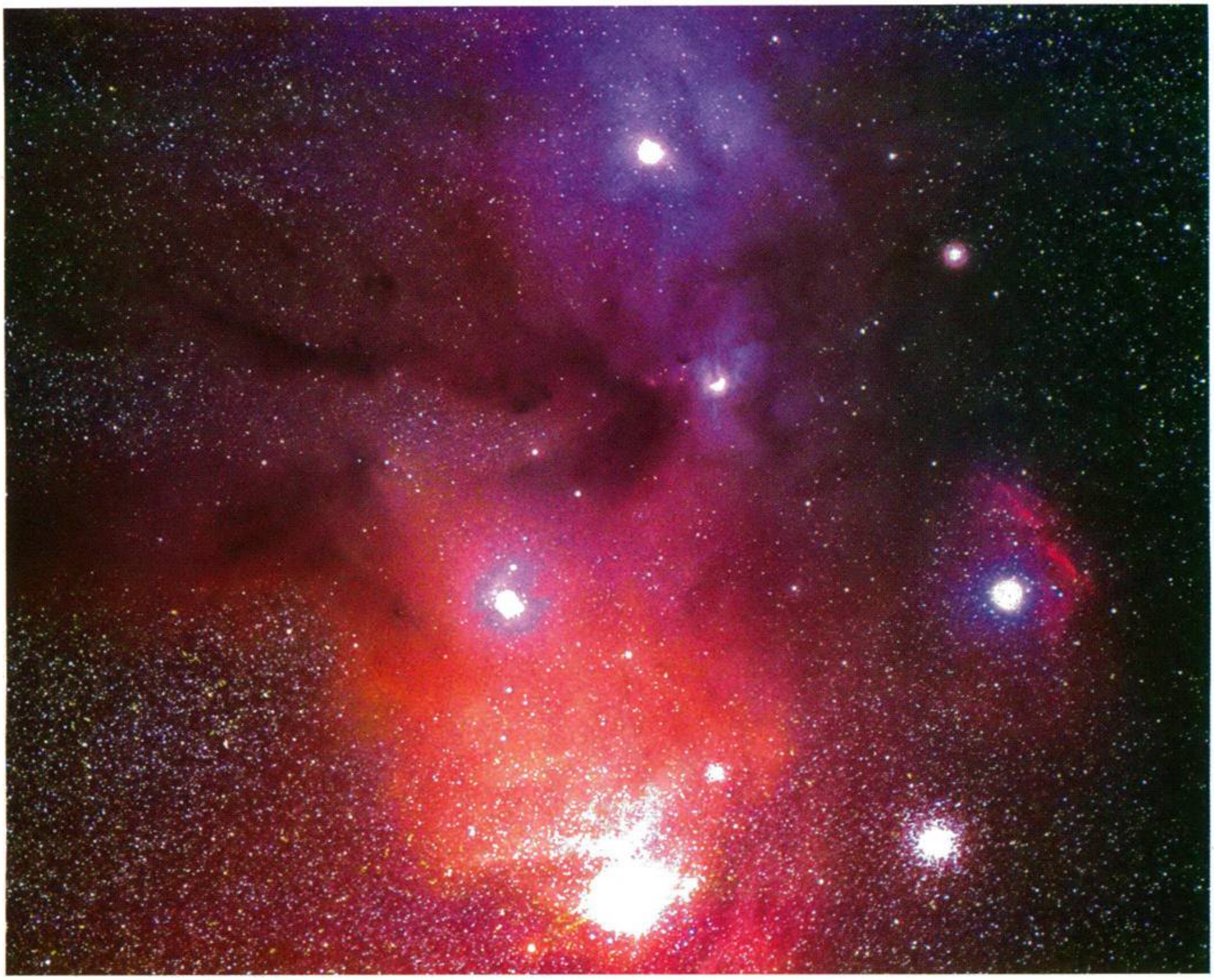
FRANK MARCHESE

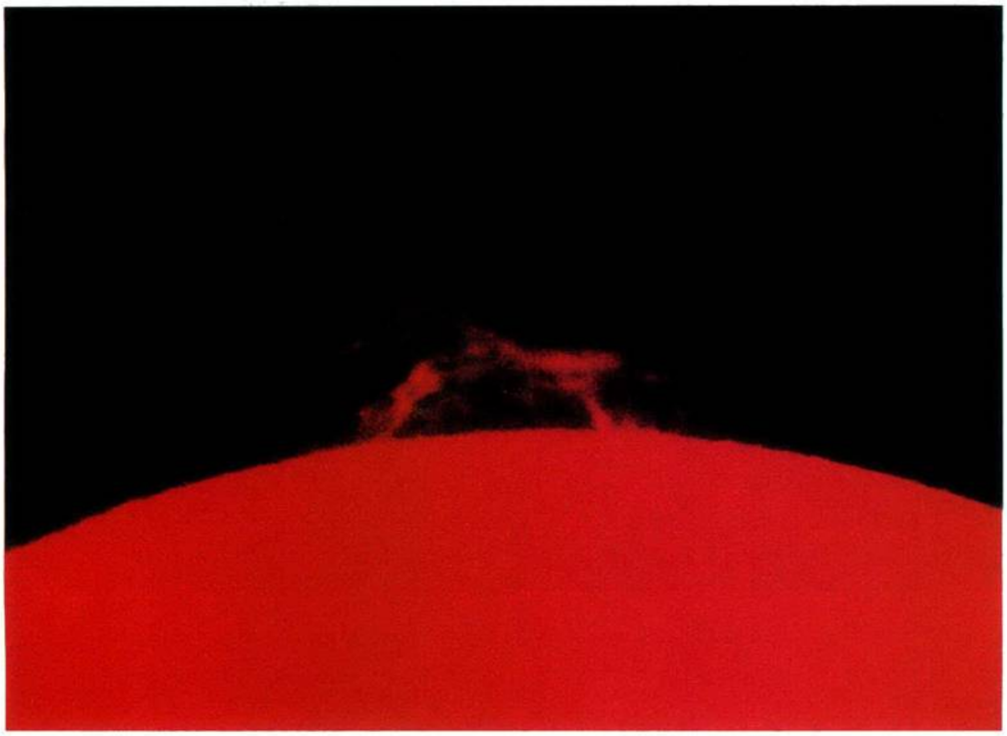
Our home galaxy's center is toward the constellation Sagittarius, seen here with the Eagle, Lagoon and Trifid nebulae. (50mm lens at f/1.8, Lumicon Deep Sky filter, Fuji HR-800 film, 20-minute exposure taken May 4, 1997)

Large Magellanic Cloud

AXEL MARTIN AND ANDREAS BÖKER

A member of our Local Group that can only be seen from the Southern Hemisphere, the LMC spans eight degrees of sky and has a faint barred spiral structure. (135mm lens at f/4.5, Kodak ProGold 400 film, 60-minute exposure)





The Rho Ophiuchi Region

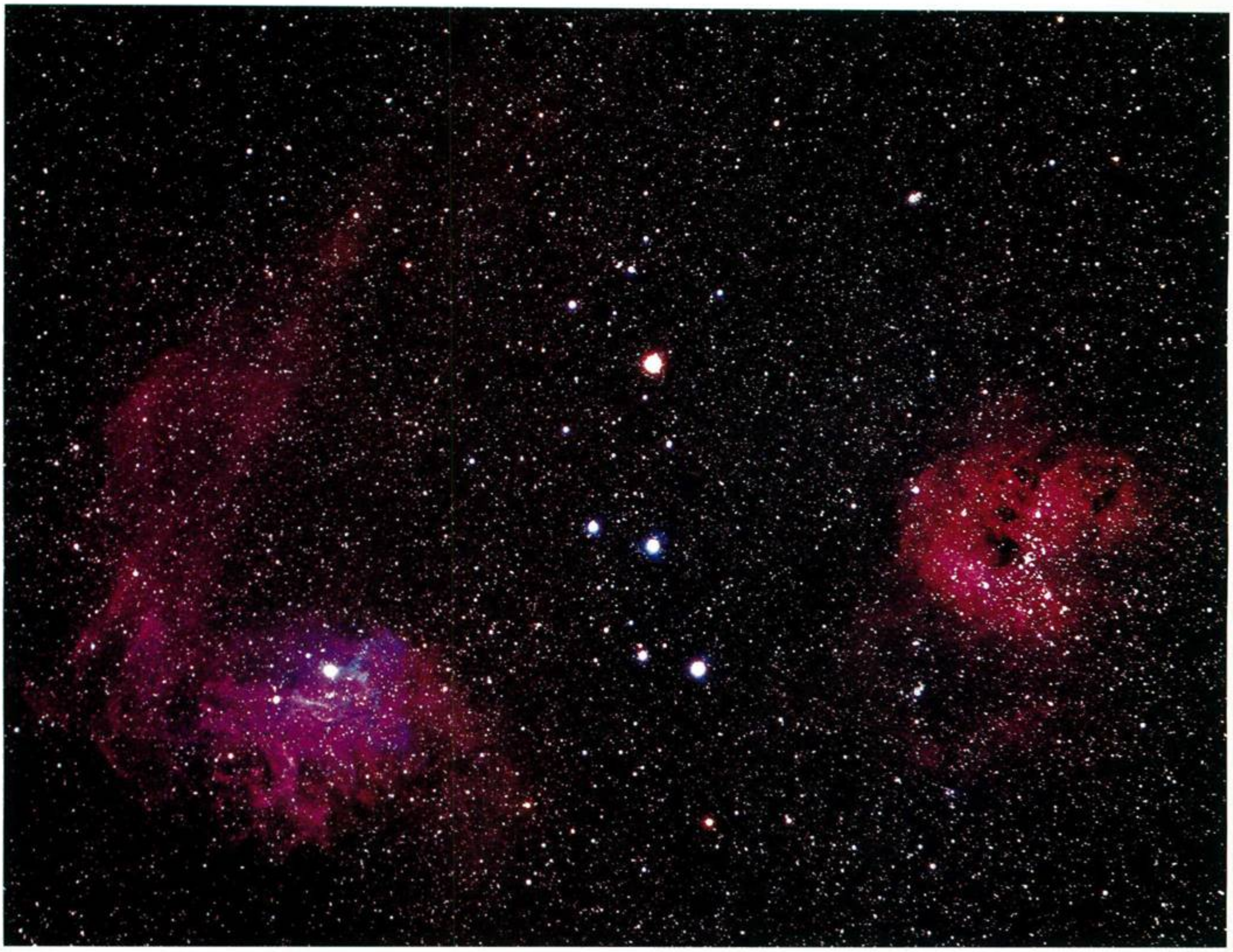
MICHAEL STECKER

The Antares-Rho Ophiuchi complex is one of the most colorful telescopic areas in the sky.
(300mm lens at f/2.8, Kodak Technical Pan film, composite of 45-minute red, 75-minute green, and 90-minute blue exposures)

Sun Prominence

DONALD J. LAMMON

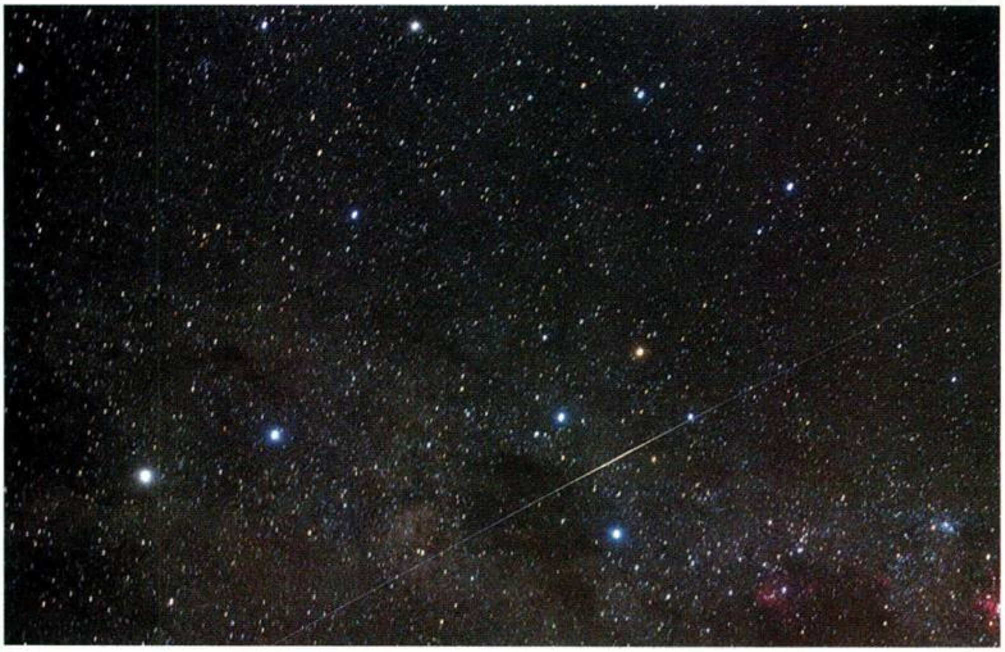
Expect to see more activity on the sun as solar maximum arrives in the year 2000.
(10-inch SCT, prime focus, DayStar Hα filter, Kodak Royal Gold 400 film, taken March 6, 1999)



The Flaming Star Nebula and IC 410

GEORGE GREANEY

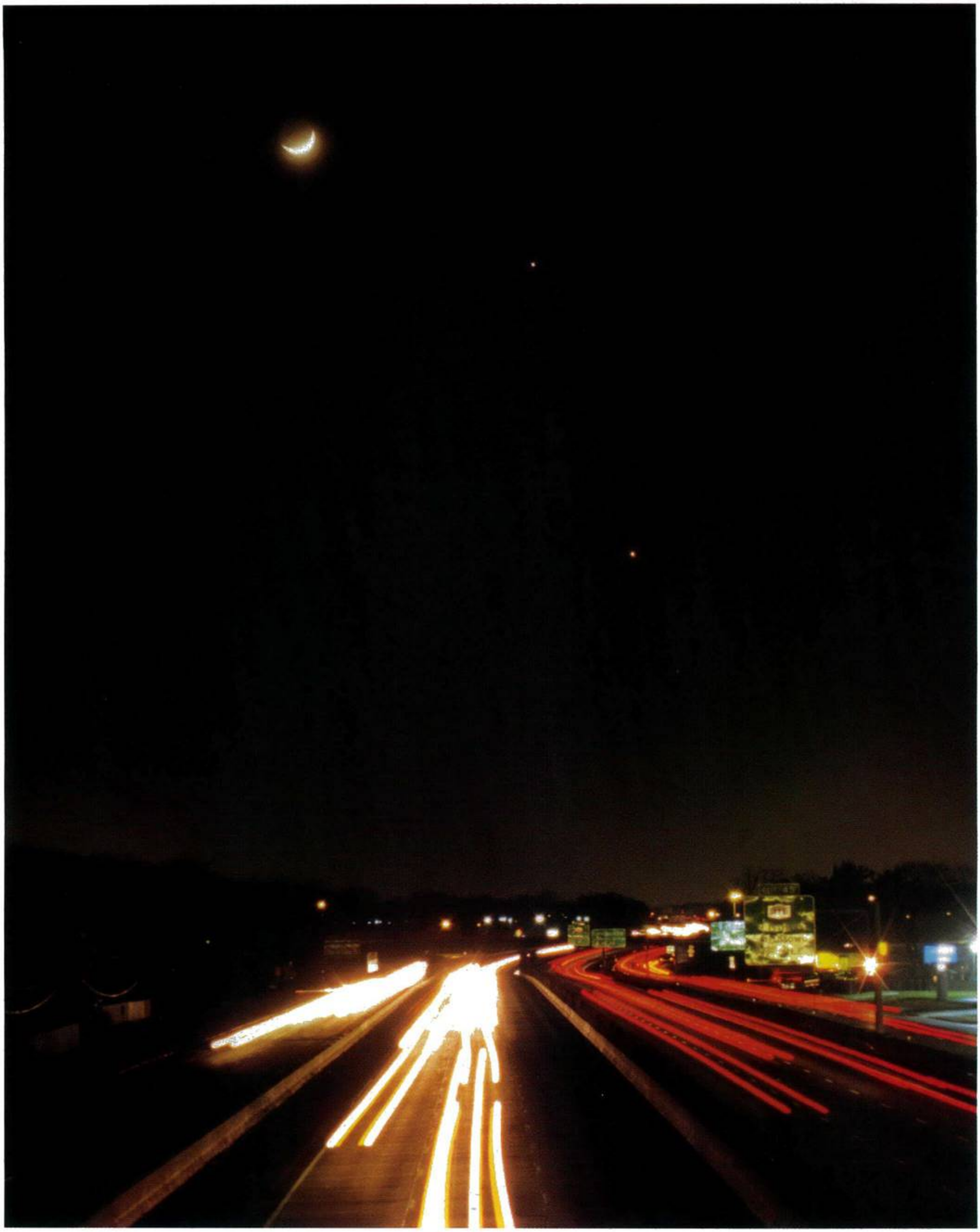
This blend of emission and reflection nebulosity contains glowing gas and sooty dust.
(6-inch f/7 refractor, composite of two 1-hour exposures)



Iridium Flare through the Southern Cross

J.C. DINIZ

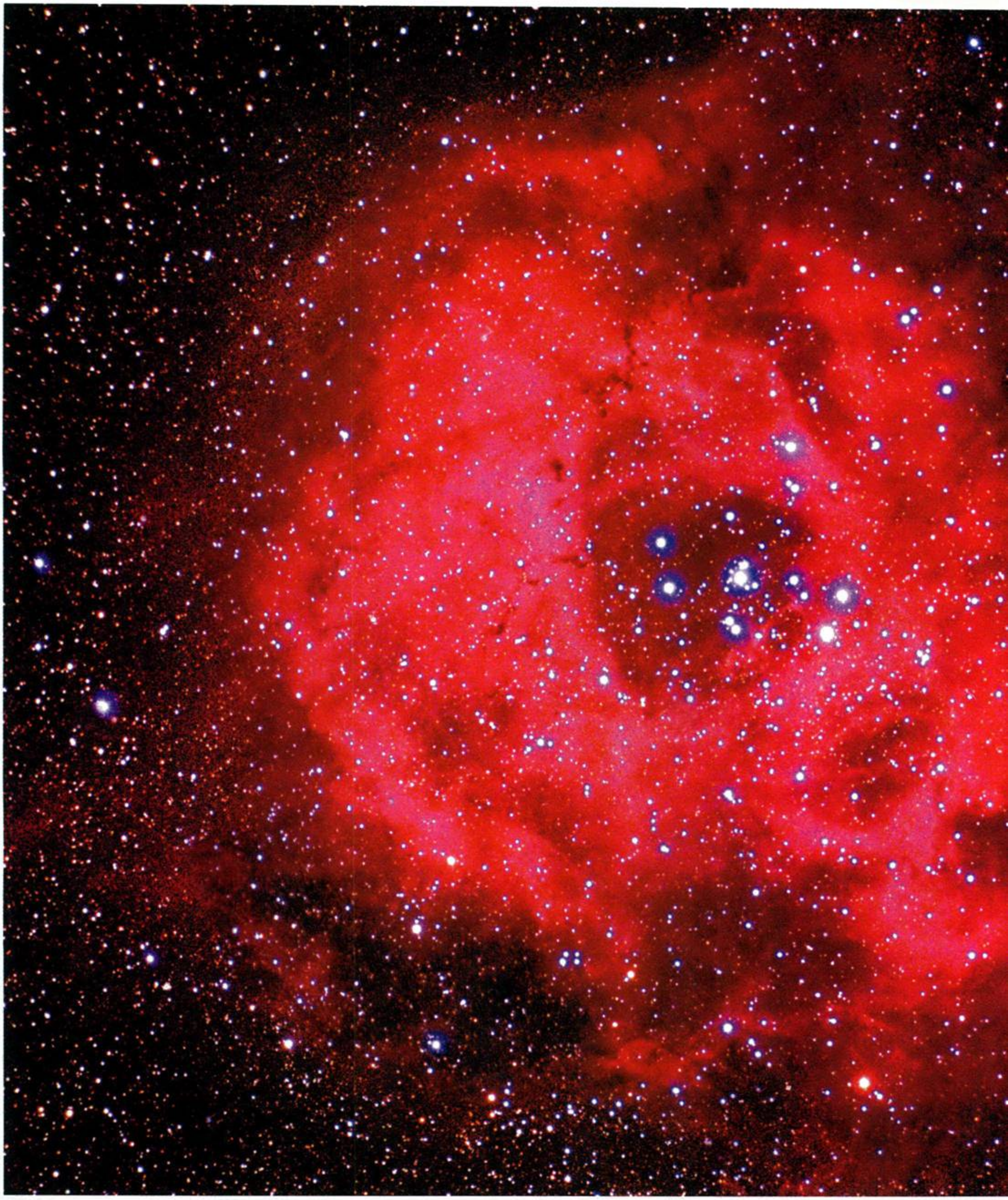
This Iridium flare (sunlight flashed from a satellite) was captured at Nova Friburgo, Brazil. Because the satellites follow a regular orbit, the time and location of their flashes can be predicted.
(50mm lens at f/2, Kodak PPF 400 ISO film, 1-minute exposure taken July 13, 1998)



Celestial Traffic

LARRY LANDOLFI

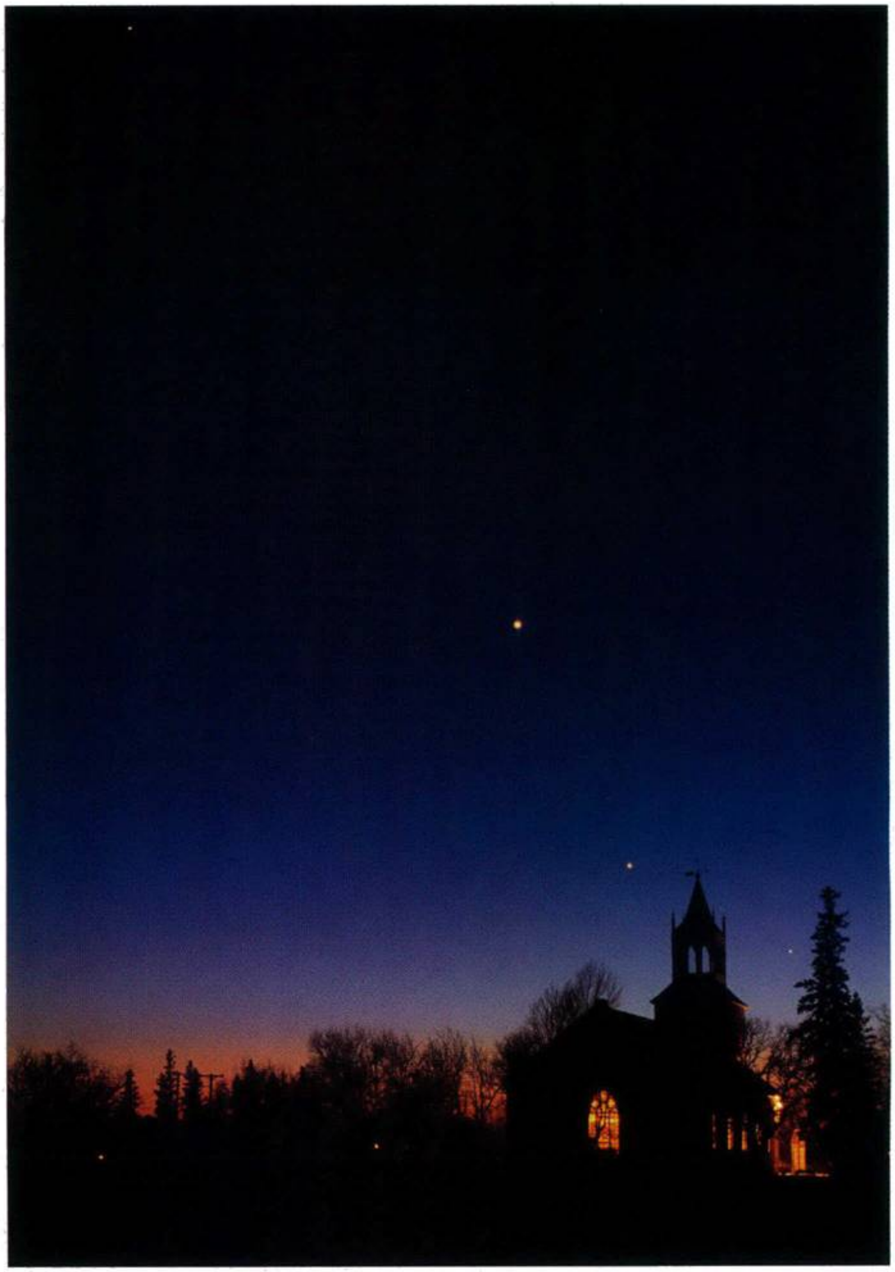
The moon, Jupiter, and Venus mirror the busy traffic of a highway.
(Taken February 18, 1999)

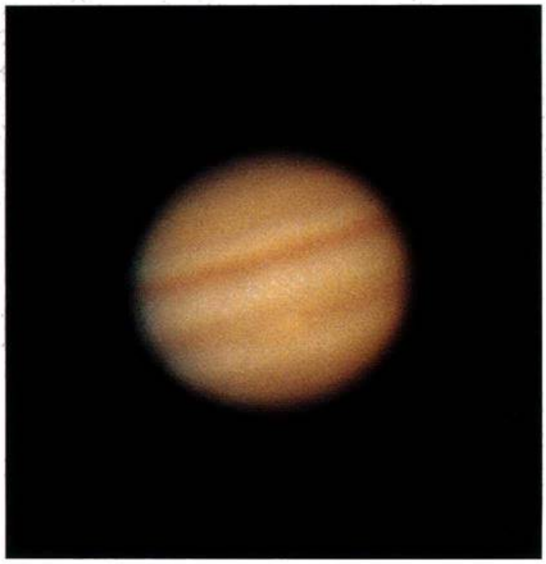


The Rosette Nebula (NGC 2237–9) in Monoceros

JASON WARE

This extensive gas cloud forms a ring around a 5th-magnitude star cluster, NGC 2244.
(6-inch f/9 refractor combined with a 12-inch f/2.2 Schmidt Camera, composite of two 60-minute exposures on Fuji HG 400 120 format film and one 30-minute exposure on Kodak Tech Pan with a #92 red filter)





Mercury, Jupiter, Venus, and Saturn

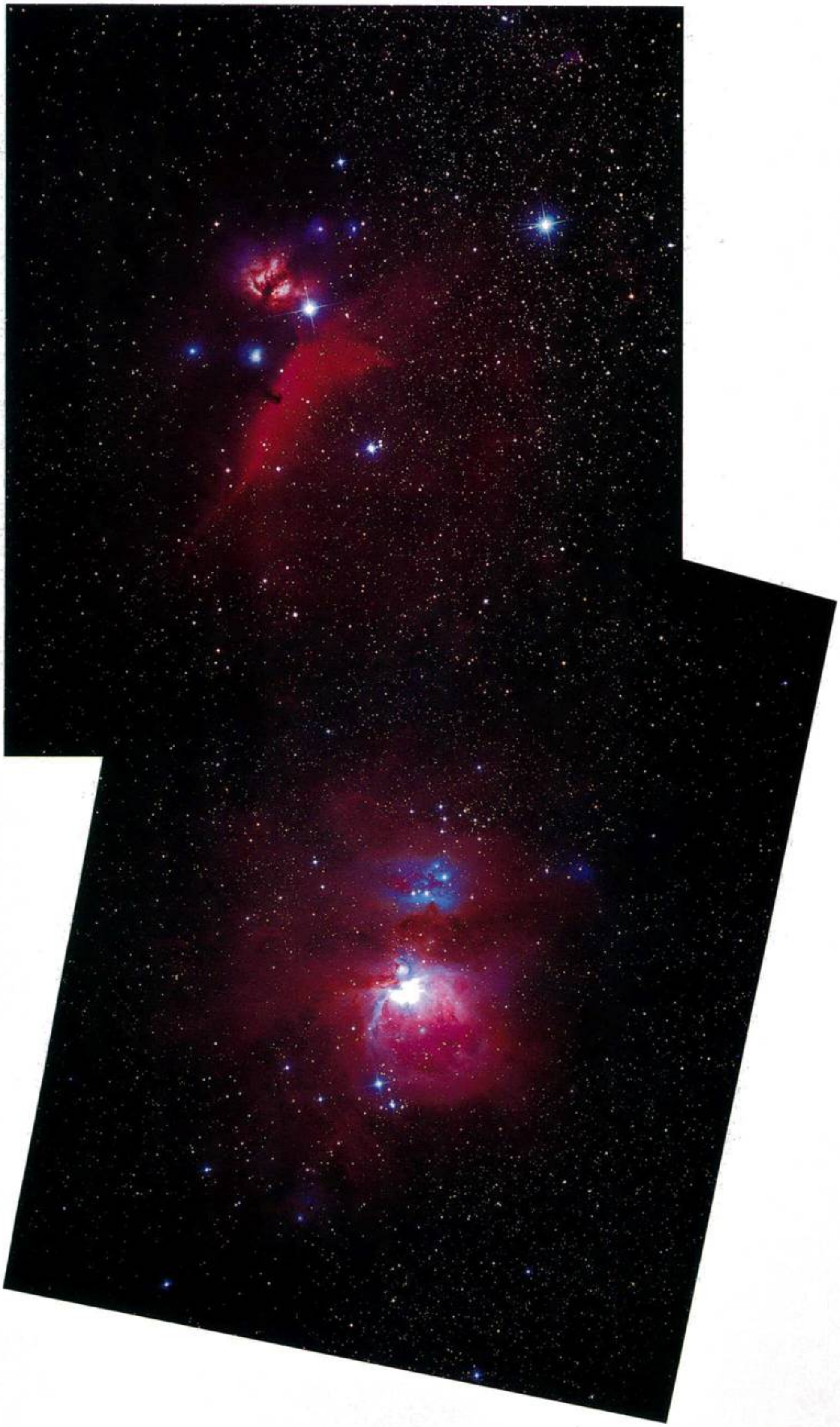
ANDY TEKAUZ

Four planets sparkle over the stained glass windows of St. Andrews-on-the-Red Church in Manitoba, Canada. (50mm lens at f/2.8, Ektachrome Elite 100 film, 5-second exposure taken March 2, 1999)

Jupiter's Cloudy Face

RON GATTIE

The dark bands on Jupiter are areas where atmospheric gases are descending, and the light zones indicate locations where gas is rising. The Great Red Spot is a storm the size of three Earths. (10-inch SCT at f/50, Kodak Elite 100 film, 1-second exposure taken in November 1998)



The Horsehead and Orion Nebulae

MACE HOOLEY

These nebulae reside in the sword of Orion. The Orion Nebula (bottom) is visible to the naked eye as a fuzzy patch, although it is 1,500 light-years away.
(10-inch f/3.4 reflector, PPF film, composite of two 30-minute exposures)

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